Los Angeles County Watershed Model Configuration and Calibration—Part II: Water Quality

Submitted to:

County of Los Angeles
Department of Public Works
Watershed Management Division
900 South Fremont Avenue, 11th Floor
Alhambra, CA 91803-1331

Submitted by:

Tetra Tech, Inc.
3475 East Foothill Boulevard
Pasadena, CA 91107

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Introduction

The first phase of developing the modeling decision framework for Los Angeles County (county) watersheds is developing a comprehensive, uniform watershed model of county watersheds to help with watershed planning and pollutant load reduction analysis. Although various watershed models were available for each of the coastal watersheds of the county, the eight earlier models varied with respect to assumptions and inputs for components such as average subwatershed segmentation size, segmentation basis, land use data source, and model parameterization. Specific changes have been recommended to create a truly regionalized modeling approach that takes advantage of the strengths of previous efforts, improves identified weaknesses, and builds on the collective efforts and advances of the past few years. In addition, model reconfiguration included incorporating capabilities for decision support, including representation of scale and land characteristics that are essential to the analysis of benefits of storm water management practices.

The first step in this process is documented in *Los Angeles County Watershed Model Configuration and Calibration—Part I* (Tetra Tech 2009a), which describes the model setup and configuration, hydrology calibration, and validation for a new regionalized watershed model. The Part I report has four primary objectives:

1. Provide a uniform and consistent representation of baseline storm water hydrology for the purpose of informing predictive representation of pollutant loading (water quality is the primary objective)
2. Expand the spatial resolution of the subwatersheds for more distributed management assessment
3. Increase the spatial resolution of climate and rainfall-runoff response (to enhance spatial resolution pollutant loading potential)
4. Represent spatially variable baseline high-flow storm water peaks and flow volumes across the regional watersheds

Building on the work in the Part I report, *Los Angeles County Watershed Model Configuration and Calibration—Part II*, focuses on the water quality aspects of model calibration. The objectives of Part II are

1. Discuss the pollutants of concern in county watersheds
2. Identify the major point source loads to the watersheds
3. Provide the pollutant flow analysis and characterization of trends
4. Discuss the water quality calibration and validation process.

The modeled pollutants of concern in the county watersheds are total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), copper (Cu), lead (Pb), zinc (Zn) and fecal coliform. Other pollutants of concern in Los Angeles County watersheds, which were not modeled include polycyclic aromatic hydrocarbons (PAHs), PCBs, pesticides, other metals (cadmium, nickel, selenium, mercury, iron, and others), cyanide, oil and grease and trash. Although only seven pollutants were addressed in the model, it is possible to incorporate other pollutants in the future. Additionally, some of the modeled pollutants can be used to represent other pollutants. For example, TSS could be used as a surrogate for organics. The transport of metals and organics in sediment transported in stormwater has been substantially documented (Buffleben et al. 2002; Caltrans 2003; Hoffman et al. 1982; Lau and Stenstrom 2005; Longanathan et al. 1997; Stein et al. 2006; Yunker et al. 2002 as cited in Tetra Tech 2009b).

Pollutant Source Assessment

Understanding the sources in a watershed is critical to developing and applying a watershed model that accurately captures the watershed loadings and their relative influence on waterbody conditions. This section identifies the potential sources of the modeled pollutants of concern (TSS, TN, TP, Cu, Pb, Zn, and fecal coliform) in the county watersheds. Pollutants can enter surface waters from both point and nonpoint sources. Point sources are identified for each pollutant, followed by a discussion of the nonpoint sources for each pollutant. Following the identification of sources, there is a discussion of how the sources are represented in the model, including the development of hydrologic response units.

Point Sources

A point source, according to Title 40 of the *Code of Federal Regulations* (CFR), section 122.3, is any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, and vessel or other floating craft from which pollutants are or could be discharged. The National Pollutant Discharge Elimination System (NPDES) program, established under Clean Water Act sections 318, 402, and 405, requires permits for the discharge of pollutants from point sources. Point sources also include stormwater that is regulated through the NPDES program.

Regulated Storm Water

Storm water runoff in the county watersheds is regulated through four types of permits: municipal separate storm sewer system (MS4) permit issued to the county, a statewide storm water permit for Caltrans, a statewide Construction Activities Storm Water General Permit, and a statewide Industrial Activities Storm Water General Permit. The Caltrans statewide storm water discharge permit authorizes storm water discharges from Caltrans properties and facilities, such as the state highway system, park facilities and maintenance yards. Most of those discharges eventually run to a city or county storm drain. The NPDES industrial general permit regulates storm water discharges and authorized non-storm water discharges from several categories of industrial facilities. That order regulates storm water discharges and authorized non-storm water discharges from 10 specific categories of industrial facilities, including manufacturing facilities, oil and gas mining facilities, landfills, and transportation facilities. Covered activities specific to county watersheds include sand and gravel operations, oil and natural gas facilities, metal plating, transportation, recycling, and manufacturing facilities.

Total Suspended Solids

TSS are particles in the water that can be trapped by a filter. High concentrations of TSS can reduce the amount of sunlight available to aquatic organisms and decrease water clarity. That leads to a number of effects including reducing aquatic plants available for consumption by higher level organisms, lower dissolved oxygen, and the impaired ability of fish to see and catch food. Other pollutants of concern can also be transported in storm water through association or attachment to TSS particles (e.g., metals, organics). TSS particles can also hold heat, resulting in increased stream temperature. Further, TSS can clog fish gills, retard growth rates, decrease resistance to disease, and prevent egg and larval development. When TSS settles on the bottom of a waterbody, eggs of fish and invertebrates are smothered, larvae can suffocate, and habitat quality is degraded (OEPA 1999).

TSS can result from storm water runoff from all types of land surfaces in the county watersheds. However, sources of TSS that are of particular concern relevant to the MS4 permit include runoff from residential, industrial and commercial lands. Roads are also expected to be a major source of sediment throughout the county.

Metals (Cu, Pb and Zn)

The four types of storm water permits in the county (MS4 permit, statewide storm water permit for Caltrans, statewide Construction Activities Storm Water General Permit, and a statewide Industrial Activities Storm Water General Permit) are all considered to have a high potential for contribution of metals to the watersheds in Los Angeles County (LARWQCB 2005). Individual sources of metals in the watershed, which are collected by MS4s and discharged to the rivers and tributaries, include automobile break pads, vehicle wear, building materials, pesticides, erosion of paint and deposition of air emissions from fuel combustion and industrial facilities (USEPA 2006). Although metal loadings specific to Caltrans properties have not been determined, it is conservatively estimated that 1.3 percent of the Ballona Creek and Los Angeles River watersheds are covered by state highways.

That estimate does not include other Caltrans properties and facilities covered under the permit. (LARWQCB 2005; USEPA 2005)

All the types of facilities covered under the industrial general permit have the potential for metal loads, especially metal plating, transportation, recycling and manufacturing facilities (LARWQCB 2005; USEPA 2006, 2005). Storm water runoff from industrial sites has the potential to contribute to metal loadings during wet weather, although during dry weather the potential is low. Discharges covered under the statewide construction general permit also have the potential to contribute metal loading from construction sites. Sediment delivered from construction sites can contain metals from construction materials and heavy equipment. Additionally, metals can leach out of building materials and construction waste exposed to storm water (Raskin et al. 2004). During redevelopment of former industrial sites, there is a higher potential for discharge sediments to contain metals. Wet-weather runoff from construction sites has the potential to contribute metal loadings; however, during dry-weather, the potential contribution of metals loading is low because non-storm water discharges are prohibited or controlled by the permit (LARWQCB 2005; USEPA 2006, 2005).

As previously stated, TSS can also harbor trace metals. During atmospheric deposition of metal-bearing particles onto surfaces (dry deposition) the particulates can become trapped within soil matrices (Lu et al. 2003).

Atmospheric deposition of trace metals, either directly to a waterbody surface or indirectly to the watershed land surface can be a large source of contamination to surface waters near urban centers. For example, dry deposition to watershed land surfaces is substantial in coastal waterbodies of Southern California with atmospheric deposition potentially contributing as much as 50–100 percent of trace metals to stormwater runoff in highly impervious, urban catchments (SCCWRP 2008). Additionally, proximity to urban areas, and in particular busy roadways, significantly increases dry deposition rates (SCCWRP 2008). While indirect dry deposition of metals can have a significant influence on the water quality of stormwater runoff, direct dry deposition in the county is not a significant factor because of the small water surface on which to receive direct deposition and because approximately 75 percent of the flow during dry weather is a result of publicly owned treatment works discharges, which overwhelm most direct sources (Sabin et al. 2006).

Although the atmospheric deposition of Pb has decreased over the past 30 years, atmospheric deposition of Cu and Zn has increased along the coast near the Los Angeles Harbor (SCCWRP 2008). Recently, aerial deposition of Cu, Zn and Pb were measured at Santa Monica Bay (Stolzenbach 2006). Table 1 compares the contributions of trace metals from aerial deposition, sewage treatment plants, industrial activities, and power plants.

Table 1. Comparison of source annual loadings to Santa Monica Bay (metric tons/year)

Metal	Aerial deposition	Non-aerial sources		
		STP	Industrial	Power plants
Chromium	0.5	0.6	0.02	0.14
Copper	2.8	16	0.03	0.01
Lead	2.3	< 0.01	0.02	< 0.01
Nickel	0.45	5.1	0.13	0.01
Zinc	12.1	21	0.16	2.4

Source: Stolzenbach 2006

While sewage treatment plants are shown to be the largest source of Cu and Zn, Pb in Santa Monica Bay is almost entirely from aerial deposition.

Dry-Weather and Wet-Weather Urban Runoff Contributions

The sources and delivery of metals can vary depending on weather and flow conditions. To evaluate all dry-weather sources of metals in the San Gabriel River watershed, the Southern California Coastal Research Project (SCCWRP) conducted two monitoring events in September 2002 and September 2003. The monitoring consisted of synoptic sampling of flow and metals concentrations from water reclamation plants (WRPs), storm drains, and open channels. The concentrations of all metals were greater in storm drains than in WRP discharges. The concentrations of all metals except Zn were greater in open channels than in WRP discharges.

Dry-weather runoff or nuisance flow and/or discharges from other NPDES permitted sources are a significant source of metals in the county watersheds (USEPA 2005, USEPA 2006, LARWQCB 2005). However, dry-weather flows are highly variable on a daily and annual basis. Metals concentrations are also highly variable between storm drain locations. During dry weather, the metals are primarily in the dissolved phase and may be more bioavailable (LARWQCB 2005, SCCWRP, 2004). In a number of county watersheds, wet-weather metal loadings are greater than dry-weather loadings, even in dry years, with wet-weather storm water runoff shown to be the dominant source of annual metals loading (LARWQCB 2005; USEPA 2006, 2005).

Fecal Coliform

Fecal coliform is an indicator of the possible presence of pathogenic organisms (e.g., enterococcal bacteria, viruses, and protozoa), which can cause human illness. The direct monitoring of those pathogens is difficult and therefore fecal coliform is used as an indicator of potential fecal contamination. Concentrations are typically reported as the count of organisms in 100 milliliters of water (count/100 mL) and can vary at a site depending on the baseline bacteria level already in the river, inputs from other sources, dilution with precipitation events, and die-off or multiplication of the organism in the river water and sediments.

According to the Total Maximum Daily Loads for Bacterial Indicator Densities in Ballona Creek, Ballona Estuary and Sepulveda Channel, most of the minor or general NPDES permitted facilities do not monitor for bacteria, so the bacterial loads associated with the discharges are largely unknown (LARWQCB 2006). Runoff in the county is regulated as a point source under the MS4 permit, the Caltrans Stormwater Permit, the General Construction and Industrial Storm Water Permits. According to the Los Angeles Harbor Bacteria TMDL—Inner Cabrillo Beach and Main Ship Channel, discharges from individual and general NPDES permits, general industrial storm water permits and general construction storm water permits are not expected to be a significant source of bacteria. The major source of bacterial contamination in the county watersheds is discharges from storm drains regulated under the MS4 permit (LARWQCB 2004; LARWQCB 2006). According to Ackerman et al. (2005) storm drains account for the majority of mass emissions of bacteria to the San Gabriel River. In-stream bacteria concentrations were consistently high and showed no apparent spatial pattern, indicating that storm drains or other in-stream sources are present throughout the watershed (Ackerman et al. 2005).

Storm drain system discharges can have elevated levels of bacterial indicators because of sanitary sewer leaks and spills; illicit connections of sanitary lines to the storm drain system; runoff from homeless encampments; pet waste; organic debris from gardens, landscaping and parks; food waste; and illegal discharges from recreational vehicle holding tanks, among others (LARWQCB 2006; USEPA 2003a). The bacteria indicators used to assess water quality are not specific to human sewage; therefore, fecal matter from animals and birds can also be a source of elevated levels of bacteria, and vegetation and food waste can be a source of elevated levels of total coliform bacteria, specifically (LARWQCB 2006).

Dry-Weather and Wet-Weather Urban Runoff Contributions

During dry-weather storm drain flows are attributable to nuisance flows caused by over-irrigation of lawns, car washing, restaurant washout and other activities in the watershed, and intermittent permitted discharges. Data available through the county MS4 Permit monitoring program and SCCWRP were evaluated as part of the Ballona Creek bacteria TMDLs to identify potential sources. Although all land use sites exceeded the objectives for bacteria, the county data set for 1994-2000 showed storm water originating from the high-density/single-family residential category had the highest densities of fecal coliform indicators, followed by commercial land use. In the SCCWRP 2001–2004 data set, the highest fecal coliform levels were from the low-density residential land use category, followed by commercial land use (LARWQCB 2006).

Nutrients (TN and TP)

Nutrients rarely approach concentrations in the ambient environment that are toxic to aquatic life; in fact, nutrients are essential in minute amounts for the proper functioning of healthy aquatic ecosystems. However, nutrient concentrations in excess of those minute needs can exert negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al. 1994). Increased plant production increases turbidity, decreases average dissolved oxygen concentrations, and increases fluctuations in diurnal dissolved oxygen and pH levels. Such changes shift aquatic species composition away from functional assemblages composed of intolerant species, benthic insectivores, and top carnivores that are typical of high-quality streams toward less desirable assemblages of tolerant species, generalists, omnivores, and detrivores that are typical of degraded streams (OEPA 1999). Such a shift in community structure lowers the diversity of the system.

The potential nutrient sources are fertilizer used for lawns and landscaping; organic debris from gardens, landscaping, and parks; phosphorus in detergents used to wash cars or driveways; trash such as food wastes; domestic animal waste; and human waste from areas inhabited by homeless. Such pollutants build up, particularly on impervious surfaces, and are washed into the waterways through storm drains when it rains. Those loads are typically highest during the first major storms after extended dry periods, when the pollutants have accumulated. Activities such as watering lawns and landscaping, washing cars, and washing parking lots and driveways can contribute pollutants between storms (USEPA 2003b). High nitrogen and phosphorus loadings are associated with urban wet-weather runoff from residential, commercial, and industrial land uses (SCCWRP 2000; LARWQCB 2003; USEPA 2003b).

Indirect atmospheric deposition is the process by which nutrients deposited on the land surface are washed off during storm events and delivered to waterbodies. Indirect atmospheric deposition of nutrients is accounted for in storm water runoff (USEPA 2003b; LARWQCB 2008a).

Dry-Weather and Wet-Weather Urban Runoff Contributions
Dry-weather contributions from storm drains were quantified for the Los Angeles River watershed (SCCWRP 2000). Storm drains were shown to contribute 34 percent of the nitrate load and only 2 percent of the TN load. The Los Angeles Regional Water Quality Control Board (LARWQCB) estimated that 78 percent of the nitrogen loads (wet and dry-weather combined) from the storm drain system were associated with urban runoff (LARWQCB 1998, 2003).

Other NPDES Permitted Facilities

There are 17 point source wastewater treatment facilities, identified in Table 2, that are considered in the modeling. Those 17 do not include the MS4 permits that are also considered point sources but behave like nonpoint sources. Because water is a limited resource in the county, many of the facilities are designed as water reclamation facilities that treat the water to levels safe enough to be used for irrigation and reuse. Some of the water reclamation facilities actually reuse 100 percent of the water that passes through. There are two groups of plants that belong to two different networks: (1) the JWPCP network, which is managed by Los Angeles, and (2) Hyperion Treatment Plant network, which is managed by the City of LA. Sewage that cannot be reclaimed or that is not discharged to the streams is routed to the two central facilities for additional treatment. The treated wastewater from those plants is discharged 2 to 5 miles offshore into the Pacific Ocean. Table 2 is a summary of major point source facilities in county watersheds, showing average treatment capacity and effluent discharge distribution (Tetra Tech 2009a). Table 3 summarizes the total number of acres per major regional watershed that are irrigated by reclaimed waste water (Tetra Tech 2009a). WRPs have been shown to be the primary source of nutrients to the waterbodies during dry-weather flows (Ackerman et al. 2005).

Table 2. Inventory of major point source discharges and effluent distribution

Facility name	Operating start date	Model outfall reach	Average treatment capacity (mgd)	Effluent distribution (percentage)			Potential pollutant contributions
				Reclaimed	Diverted	Discharged	
Tapia Water Reclamation Plant (WRP)	1965	3008	9.5	60%	0%	40%	bacteria, nutrients
Burbank WRP	1966	6602	9	44%	0%	56%	metals, nitrogen
Malibu Mesa WRP	unknown	3209	0.2	unknown	0%	variable	
West Basin Municipal Water District	unknown	2055	unknown	unknown	0%	unknown	
JWPCP Network	unknown	n/a	300	unknown	0%	To Ocean	
• La Cañada WRP	1962	n/a	0.2	100%	0%	0%	
• Long Beach WRP	1973	n/a	25	20%	80%	0%	
• Los Coyotes WRP	1970	n/a	37	14%	86%	0%	
• Pomona WRP	1966	n/a	13	100%	0%	0%	
• San Jose WRP	1971	n/a	100	35%	65%	0%	
• Whittier Narrows WRP	1962	n/a	15	100%	0%	0%	nitrogen
Saugus WRP	1962	4117	7	0%	0%	100%	nitrogen
Valencia WRP	1967	4091	21.6	variable	0%	variable	nitrogen
Hyperion Treatment Plant Network	1950	n/a	350	unknown	0%	To Ocean	
• Terminal Island WRP	1935	n/a	4.5	unknown	0%	External	bacteria
• Donald C. Tillman WRP	1985	6870	80	33%	3%	63%	metals, nitrogen
• Los Angeles-Glendale WRP	1976	6506	20	23%	3%	65%	metals, nitrogen

mgd = million gallons per day

Table 3. Total reclaimed water discharge area by major watershed

Major regional watershed	Total reclaimed water discharge area (acres)
Dominguez Channel	2
Los Angeles River	815.5
San Gabriel River	7,279.2
Santa Clara	95

Nonpoint Sources

A nonpoint source is a source that discharges to waters of the United States via sheet flow or natural discharges and are not regulated under the U.S. Environmental Protection Agency's (EPA's) NPDES program. Because of the degree of urbanization in the county, runoff that would normally be considered a nonpoint source is conveyed through the MS4 and is therefore considered a point source. In general, nonpoint source pollutant contributions are minimal in the county watersheds. However, some do exist and can have larger impact in undeveloped or less urbanized areas of the county. The following provides a summary of the types of nonpoint sources that are expected in the county.

Total Suspended Solids

Nonpoint sources of TSS in the county include erosion and runoff from agricultural and undeveloped lands.

Metals

Natural background loading of metals is a potential source to the watersheds, although it is unlikely to be a source during dry weather. During wet-weather conditions, metals concentrations from natural areas are below concentrations found at developed sites (USEPA 2006).

Direct atmospheric deposition is a potential source of metals to the watershed; however, because only a small percentage of the watershed surface area is covered by water, direct deposition can be considered insignificant relative to either the annual dry-weather loadings or the total annual loading (USEPA2005).

Indirect atmospheric deposition of metals to the land surface, which can then be washed off into waterbodies during rain events can be a significant contributor of metals. During dry weather, the loading contributions can be roughly three to four orders of magnitude larger than direct atmospheric deposition (Sabin et al. 2004 as cited in USEPA 2005). Loadings of metals associated with indirect atmospheric deposition are accounted for in the storm water loading estimates.

Nutrients

Effluent irrigation from water reclamation facilities is considered a source of nitrogen and phosphorus, with higher contributions during the summer (USEPA 2003a; Tetra Tech 2002).

The TMDLs for bacteria and nutrients in the Malibu Creek watershed indicated that septic systems are still used in low-density rural residential areas and a few communities in the watershed. Additionally several commercial septic systems are in shopping centers and commercial areas in the vicinity of Malibu Lagoon (USEPA 2003a). Failing septic systems are a potential source of nutrients in areas of the county not served by regional sewage collection systems.

In areas of county watersheds with undeveloped land, runoff from open space can contribute nutrients to receiving waters. For example, more than 75 percent of the Malibu Creek watershed is undeveloped land (open space) consisting primarily of chaparral, scrub, and woodlands, with smaller areas of grasslands and forests. Runoff from those areas contributes nutrients to the waterways in both particulate and soluble forms. Particulate forms generally predominate and are introduced through the erosion of soils that contain organic litter from the overlying vegetation. Soluble nutrients are released during litter decomposition and can enter the waterways as a component of surface runoff or through shallow groundwater transport. Wildlife and waterfowl waste can also contribute to the nutrient load in lakes and the undeveloped/recreational portions of the watershed (USEPA 2003b; LARWQCB 2008a).

Agricultural areas consisting of pastures, grazing land, orchards and vineyards that exist in the county (e.g., throughout the Malibu Creek watershed) represent a potential sources of nutrients. The nutrient sources from agricultural areas include fertilizers applied during cultivation; organic litter from the plants, grasses, or trees; erosion of the surface soils; waste accumulation from grazing animals; and soluble nutrients released during the decomposition and mineralization of plant litter and animal waste. Horse and livestock manure also contribute to the nutrient load in the Malibu Creek watershed (USEPA 2003b). Agricultural areas are limited in the county and likely represent a small portion of nutrient loadings.

Multiple studies have shown that aerosols in the ambient air of greater Los Angeles contain many toxic constituents and nutrients that can cause eutrophication in marine ecosystems (Arey et al. 1989; Young et al. 1976; Lu et al. 2003).

Golf courses in the county can be major sources of nutrients because of high levels of fertilizer application and excess watering (USEPA 2003b; LARWQCB 2008a).

Internal loading of nutrients via sediment release through wind resuspension and bioturbation, as well as plant decomposition, are potential sources of nutrients in the lakes and lagoons throughout the county. Although estimates of nutrient loads associated with sediments are relatively minor on a watershed basis, in lagoons and lakes, the release from the sediments can have a major effect on nitrogen and phosphorus concentrations especially in the summer (USEPA 2003b; LARWQCB 2008a).

Other minor nutrient contributors in the county include direct atmospheric deposition of nutrients onto waterbodies, background nutrients from shallow groundwater, and tidal inflow to Malibu Lagoon (USEPA 2003b; LARWQCB 2008a). Direct atmospheric deposition to the receiving waters is a relatively minor contributor to the annual nitrogen load of the Los Angeles River watershed, estimated at just under 1 percent (LARWQCB 1998 as cited in USEPA 2005). In the Malibu Creek watershed direct atmospheric deposition accounts for about 1 percent of the TN load and about 0.1 percent of the TP load. During the summer, atmospheric contributions increases to 5 percent of the nitrogen and 0.5 percent of the phosphorus loads (USEPA 2003b).

Bacteria

Nonpoint sources of bacteria in the county can include wildlife, septic systems, agricultural areas and site-specific inputs (e.g., beach use inputs). Wildlife sources can include birds, waterfowl, and other wildlife. Bacteria inputs from failing septic systems could be a source in areas of the county not served by regional sewage collection systems. Coastal areas of the county can be subject to a number of bacteria sources, including swimmer washoff, trash on the beach washing into the water, local feral cat contributions, sidewalk washdowns, landscape irrigation, marina activities such as waste disposal from boats, boat deck and slop washing, and natural sources from wildlife (LARWQCB 2004).

Undeveloped areas of the watershed might include bacteria inputs from agricultural sources (e.g., horses and livestock) or wildlife contributions. For example, with more than 75 percent of the Malibu Creek watershed undeveloped, wildland, wildlife and waterfowl are potentially significant sources of fecal coliform (USEPA 2003a).

Pollutants of Concern Not Addressed in the Model

Toxic Organic Chemicals

Fertilizers used for lawn and landscape maintenance of municipal areas are a source of metals and organic chemicals. Fertilizers, herbicides, and pesticides contain metals, such as cadmium, Cu, mercury, Zn, Pb, iron, and manganese. Residential fertilizers and pesticides also contain toxic chemicals such as dioxins, organophosphates, and organochlorides. Concentrations of certain pesticides, such as diazinon and chlorpyrifos, are found in higher concentrations from residential areas than agricultural areas because they are so heavily used in home applications (Katznelson and Mumley 1997; McPherson et al. 2005; Schiff and Sutula 2001 as cited in Tetra Tech 2009b).

In addition to the fertilizers and pesticides used in commercial areas, runoff from parking lots contains oil, grease, and litter. Litter loads from commercial facilities are a major source of chemicals from the breakdown of trash. Phthalate esters, which had been released from the breakdown of paper, plastic bags, and Styrofoam, were found in large concentrations in the Los Angeles region runoff (Stenstrom et al. 1998 as cited in Tetra Tech 2009b). Organic chemicals, such as phthalate esters are also associated with PVC manufacturing plants, textiles, paper mills, landfills, and incinerators (Makepeace 1995 as cited in Tetra Tech 2009b).

Commercial areas might also have toxic contaminants from dry cleaners, degreasing facilities, firing ranges, fuel terminals, car washes, car repair areas, paint stripping facilities, and others. Commercial areas with significant amounts of hazardous chemicals are reported by the Resource Conservation and Recovery Act and discussed in later sections.

PAHs, a group of more than 200 different chemicals, are found in nature in coal and crude oil and in emissions from combustion of fossil fuels, forest fires, and volcanoes. Most PAHs entering the environment are formed during burning (coal, oil, wood, gasoline, garbage, tobacco, and other organic material) or in certain industrial processes. The primary source of PAHs to Ballona Creek and Estuary is urban stormwater runoff. Research by Stein et al. (2006 as cited in Tetra Tech 2009b) found that the dominant source of origin was pyrogenic (combustion of organic matter) in the LA region that were deposited through atmospheric deposition.

Trash

Trash is a major pollutant of concern in the Los Angeles County watersheds. The major source of trash is litter, which is discarded to the lakes, creeks, and channels in the county (LARWQCB 2008b). The three primary transport mechanisms for trash are through storm drains, which are a point source, and wind action and direct disposal, which are nonpoint sources. Trash that is deposited throughout the watershed is transported through the storm drains during rainfall events. This trash is eventually discharged into bodies of water. Wind action can blow trash from the land into the lakes, channels and creeks, and direct disposal is direct dumping or littering into the waterbodies.

Source Representation in the Model

To capture the pollutant loading of sources, watershed models are typically set up to include a suite of land uses that represent a variety of sources. Such land uses form the basis of the watershed model and the representation of the hydrology, pollutant generation and accumulation, and resulting pollutant runoff and delivery to receiving waterbodies. On the basis of the major pollutants and associated sources in the county, the model was set up to include land uses representing different types of urban, residential, commercial, industrial, transportation and vacant areas. To further characterize watershed land and how it affects the watershed hydrology and pollutant delivery, hydraulic response units (HRUs) were developed for the entire watershed to account for soil type and slope in addition to the land use type.

Los Angeles County Watershed Model Configuration and Calibration—Part I outlines the process for developing HRUs for all county watersheds included in the model. The HRUs are based on land use, hydrologic soil group, and slope. Hydrologic and water quality parameters, which are influenced by land surface and subsurface characteristics, vary throughout the watersheds. Pollutant loading, which is highly correlated to land use practices, also varies throughout the watersheds. The HRUs form the basis for distributing hydrologic and water quality parameters necessary in the Loading Simulation Program C++ (LSPC) used to simulate the hydrology and transport of sediment and metals in the county watersheds (Tetra Tech 2009a).

Table 4 is a summary of HRUs for the county regional watersheds modeling area.

Table 4. HRU distribution in Los Angeles County regional watersheds

HRU	Impervious/ pervious	HRU area (acre)	Percent of total HRU area
Urban grass (irrigated)	Pervious	301,011	15.1%
Urban grass (non-irrigated)	Pervious	101,030	5.1%
HD single-family residential	Impervious	91,386	4.6%
LD single-family residential moderate slope	Impervious	2,482	0.1%
LD single-family residential steep slope	Impervious	1,701	0.1%
Multifamily residential	Impervious	51,677	2.6%
Commercial	Impervious	54,861	2.8%
Institutional	Impervious	31,832	1.6%
Industrial	Impervious	69,731	3.5%
Transportation	Impervious	28,007	1.4%
Secondary roads	Impervious	75,685	3.8%
Agriculture moderate slope B	Pervious	5,914	0.3%
Agriculture moderate slope D	Pervious	14,477	0.7%
Vacant moderate slope B	Pervious	47,592	2.4%
Vacant moderate slope D	Pervious	39,682	2.0%
Vacant steep slope A	Pervious	23,639	1.2%
Vacant steep slope B	Pervious	271,272	13.6%
Vacant steep slope C	Pervious	269,337	13.5%
Vacant steep slope D	Pervious	498,743	25.0%
Water	—	13,133	0.7%

While the objective of the watershed modeling is focused on storm water representation, accounting for irrigation and its effect on groundwater and baseflow will help to provide an estimate for load contributions associated with urban irrigation flows during the summer months. Effective irrigation coefficients were developed for *irrigated urban grass* and all *agriculture* HRUs. Of the 17 point sources considered in the modeling, many are water reclamation facilities. Those facilities treat wastewater to levels safe enough to be used for irrigation and reuse. Some of the facilities reclaim 100 percent of the effluent. The reclaimed water is accounted for in the model as supply water for irrigation to designated pervious land areas, rather than as traditional point source discharges to streams.

Water Quality Data Analysis

SCCWRP collected land use-specific storm water monitoring data and used in developing the regional modeling approach. The data were analyzed to highlight and confirm trends in pollutant behavior for model parameterization. Table A-1 in Appendix A is an inventory and summary of the storm water monitoring data used for that analysis.

To assess how representative the data collection effort was for informing model parameterization, the associated storm events were compared against 20-year rainfall duration intervals for the highest and lowest volume rainfall gages closest to the monitoring locations, Old Tapango (1050) and Long Beach (1254), respectively. Figure 1 shows rainfall magnitude for SCCWRP land use monitoring data versus rainfall duration intervals at the nearby rainfall gages. That confirms that the SCCWRP monitoring data collected between 2001 and 2005 capture a wide range of storm conditions, from the 15-percentile level all the way to the 95-percentile rainfall magnitude, compared with 20 years of rainfall records.

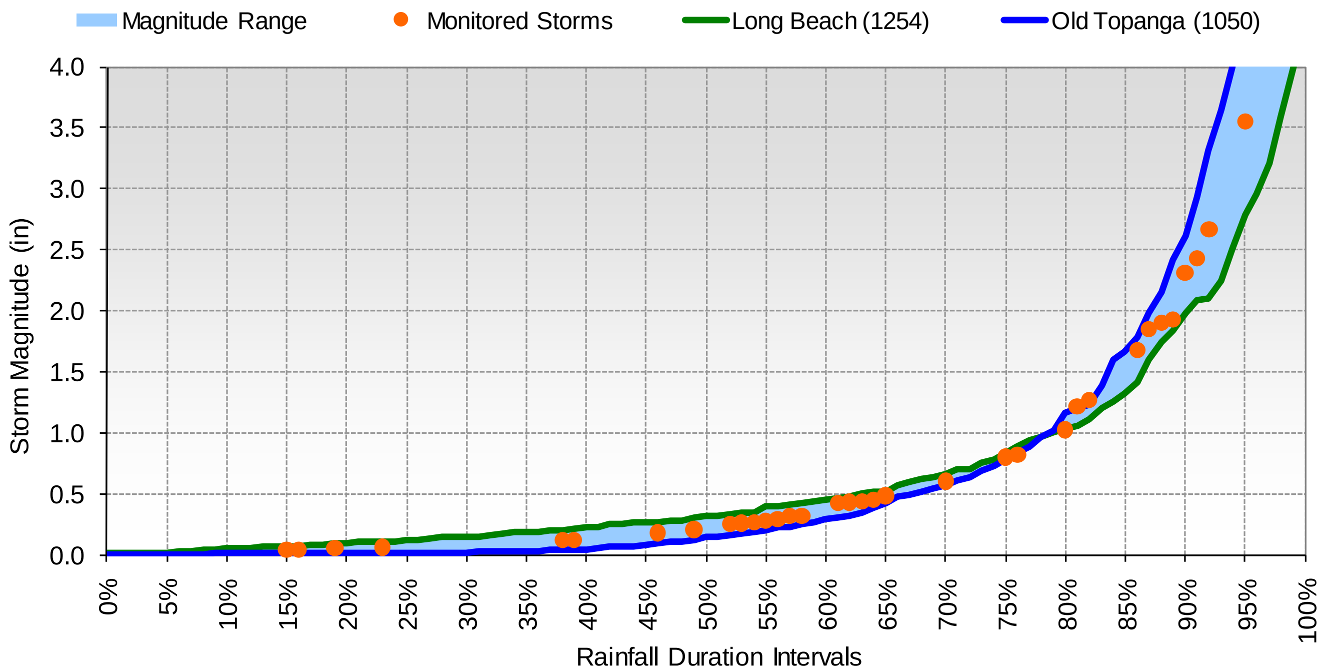


Figure 1. Rainfall magnitude for SCCWRP land use monitoring data versus rainfall duration interval ranges at nearby rainfall gages.

Table 5 shows the land use distribution in the county regional watersheds and a simplified set of HRU groupings for the land cover distributions in the model. The predominant HRU-groups in each category are shaded. Buildings, pavement and urban grass are the dominant land cover groups among the storm water monitoring sites identified as residential, commercial, and industrial. Table 6 presents the average flow-weighted concentration by general category for both the land use monitoring sites and the mass emission monitoring sites.

Table 5. HRU land cover category distribution for SCCWRP land use monitoring sites (with dominant HRU types)

Code	General category	Specific type	Total area (acres)	HRU land cover distribution in the model				
				Agricultural	Buildings pavement	Open space	Road surface	Urban grass
LU01	Residential	HD Mixed	181.5	0%	49%	1%	14%	35%
LU02	Residential	HD Pets	15.5	0%	22%	10%	20%	48%
LU03	LD Residential	LD/Grass	24.6	0%	2%	5%	4%	89%
LU04	LD Residential	LD/Grass	39.3	0%	3%	5%	1%	91%
LU06	Commercial	Roads	560.2	0%	57%	6%	29%	9%
LU07	Commercial	Mall	4.7	0%	81%	0%	14%	5%
LU08	Commercial	No Homeless	18.5	0%	84%	0%	7%	9%
LU09	Industrial	Mixed	750.6	0%	77%	1%	7%	15%
LU10	Industrial	Food	3.5	0%	0%	94%	5%	1%
LU11	Industrial	Auto	4.3	0%	39%	17%	19%	25%
LU13	Industrial	Oil	7.6	0%	47%	0%	0%	53%
LU14	Agricultural	Mixed	222.6	75%	6%	0%	2%	16%
LU15	Agricultural	Nursery	54.6	85%	2%	2%	0%	12%
LU17	Agricultural	Horse	7.7	100%	0%	0%	0%	0%
LU19	Industrial	Rail	9.0	0%	11%	43%	41%	5%
LU20	Commercial	Gas	0.7	0%	93%	0%	3%	4%
LU24	LD Residential	Rural	688.7	0%	1%	77%	0%	22%
LU25	Residential	HD	35.4	0%	30%	0%	12%	58%

Table 6. Average EMCs for SCCWRP storm monitoring data by general land use group

General land use	Average flow (cfs)	TSS (mg/L)	Total Cu (µg/L)	Total Pb (µg/L)	Total Zn (µg/L)	TP (mg/L)	Fecal coliform (#/100 mL)
Agricultural	8.1	354.7	33.2	10.2	112.3	0.01	65,207
Commercial	1.3	164.8	98.2	85.0	665.9	0.98	43,103
Industrial	5.1	149.7	30.0	20.3	691.3	0.02	1,504
LD Residential	0.5	58.3	15.9	4.1	59.6	0.13	19,110
Residential	2.7	152.5	12.8	4.7	91.6	0.20	6,685
ME01	644.9	459.7	106.9	64.0	392.8	1.53	17,042
ME02	1,403.4	733.5	134.6	97.1	556.6	2.08	79,746
ME03	1,259.6	434.7	42.2	36.6	283.3		301
ME04	488.1	226.3	42.4	42.5	245.9		10,025
ME05	1,609.6	264.3	58.7	55.2	367.8	0.13	22,735
ME06	2.5	68.5	10.3	3.6	29.3		6,019
ME07	71.1	566.8	59.8	23.3	239.0	0.38	2,105

EMC = event mean concentration; cfs = cubic feet per second; µg/L = micrograms per liter; mg/L = milligrams per liter

The following sections summarize the land use-specific storm water data for each pollutant of concern.

Total Suspended Solids

As shown in Figure 2, agricultural lands had the highest concentrations of TSS, while low-density residential had the lowest. These land uses are aggregated over all subcategories within the general land use categories. Figure 3 and Figure 4 show the event mean concentration and interquartile ranges of TSS from various commercial and residential land use monitoring sites for different storm sizes. The figures show concentrations broken down into subcategories of land uses. Overall, high-density residential land use has the highest concentration of sediment within the county watersheds, while commercial areas with high road densities had the highest concentrations of sediment in the commercial land use category.

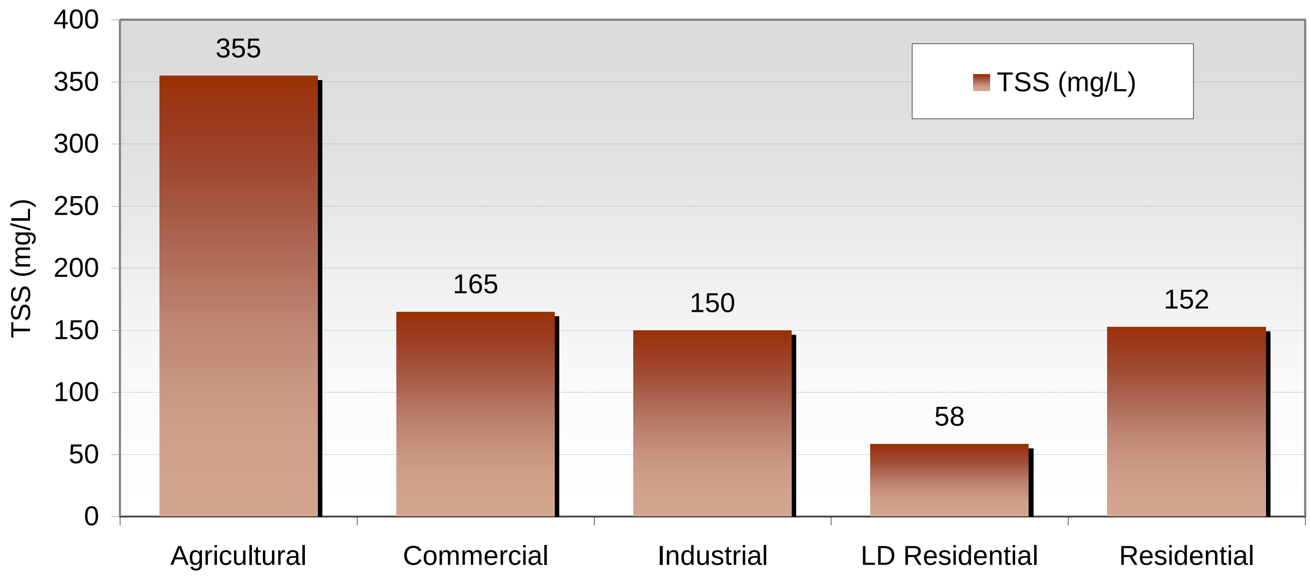


Figure 2. TSS concentration (mg/L) by land use category.

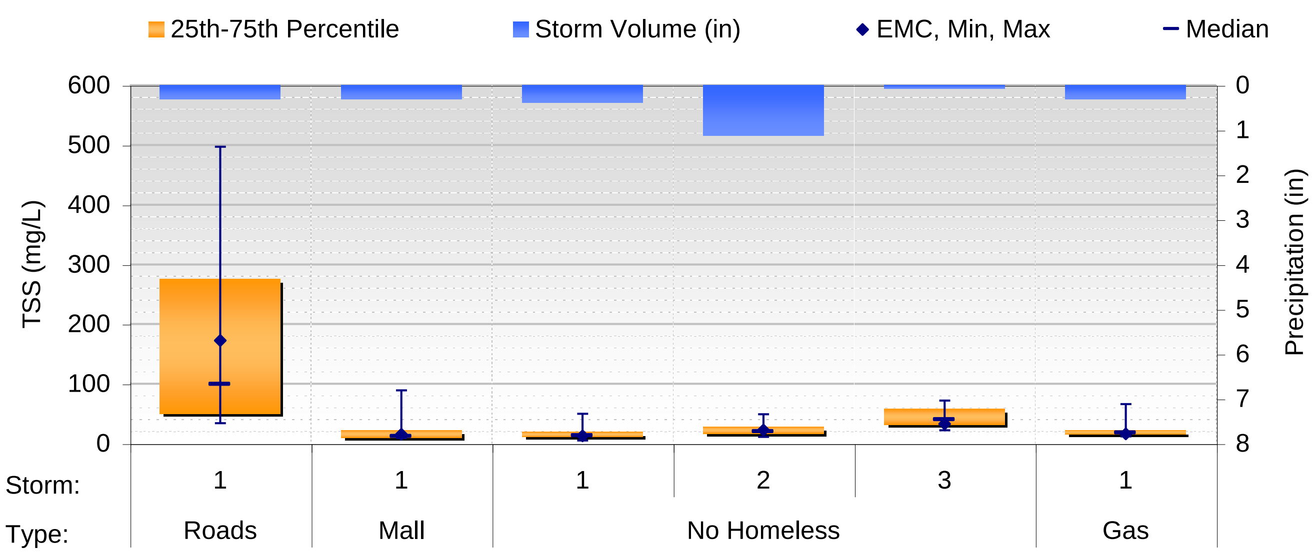


Figure 3. Commercial land use monitoring sites summary for TSS (mg/L).

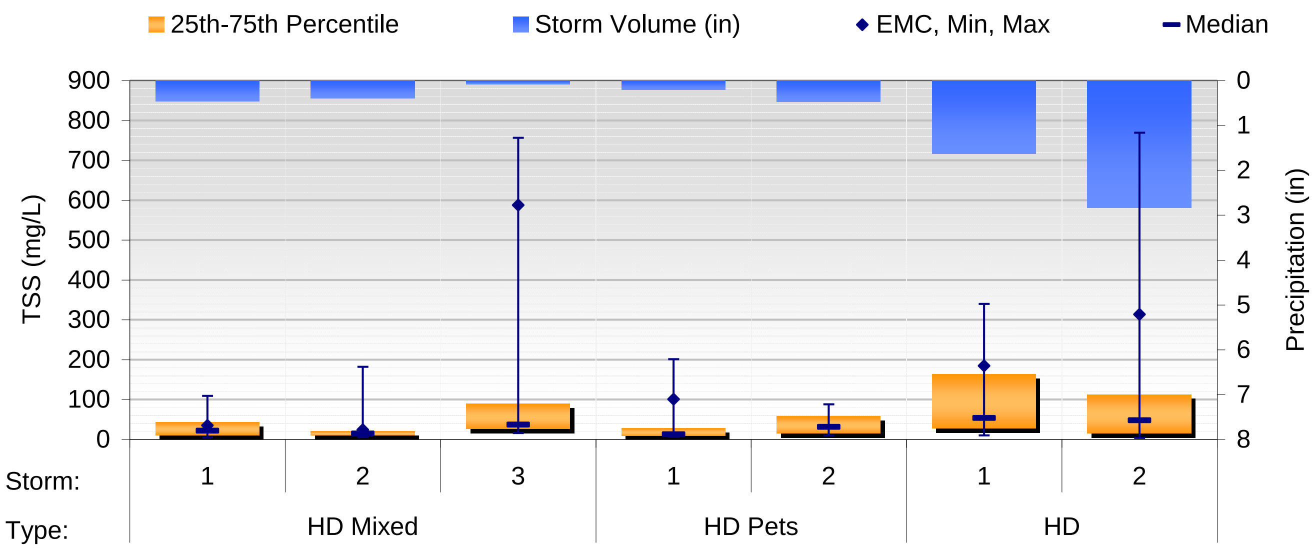


Figure 4. Residential land use monitoring sites summary for TSS (mg/L).

Nutrients

Overall, commercial land use had the highest concentrations of TP of all land uses, as shown in Figure 5. Figure 6 shows event mean concentration and interquartile ranges of TP at residential land use monitoring sites. TP concentrations tend to follow TSS concentrations, shown in Figure 4.

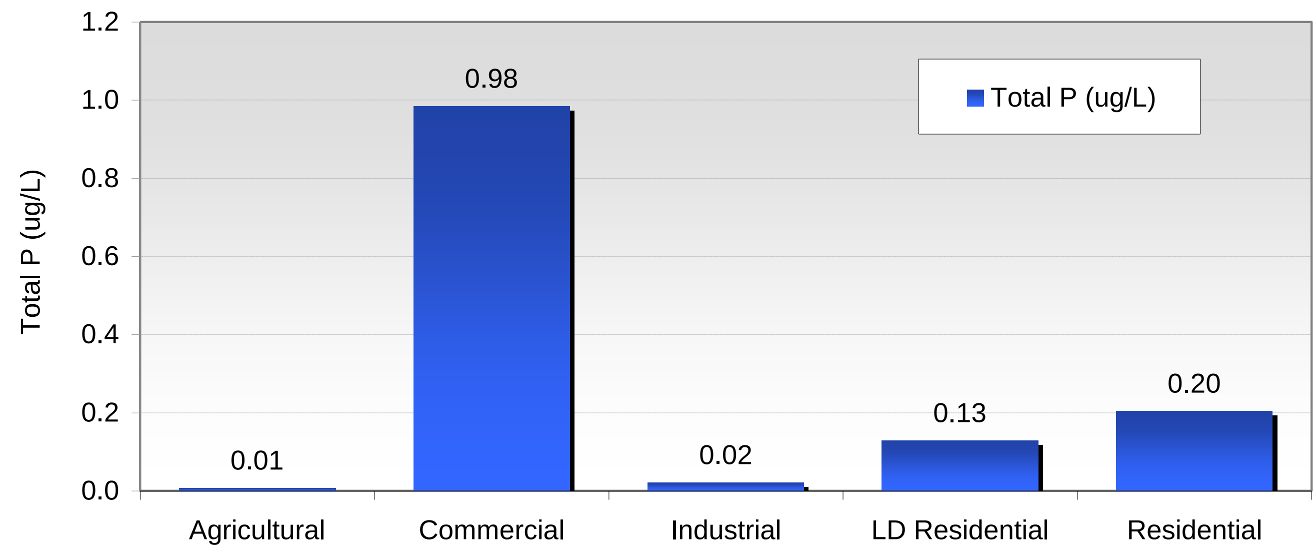


Figure 5. TP concentration (mg/L) by land use category.

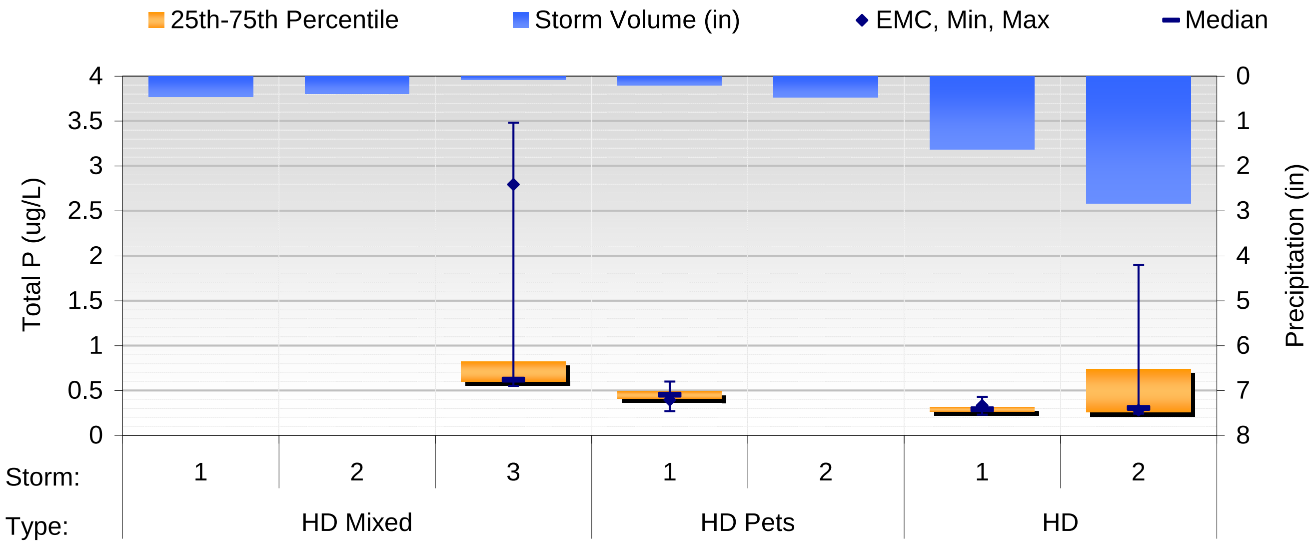


Figure 6. Residential land use monitoring sites summary for TP (µg/L).

Metals

Commercial land uses are the largest contributors of Cu and Pb and nearly as significant a source of Zn as industrial land uses, as shown in Figure 7. Residential land use contributes relatively low levels of metals to storm water runoff, though areas with relatively higher road area tended to have higher metals concentrations.

Figure 8 shows the total Cu concentrations at various commercial land use monitoring sites. Commercial, and industrial land uses have the highest metals concentrations. The *Roads* commercial area had the highest percentage of secondary road surface area and consistently has high sediment and metals concentrations.

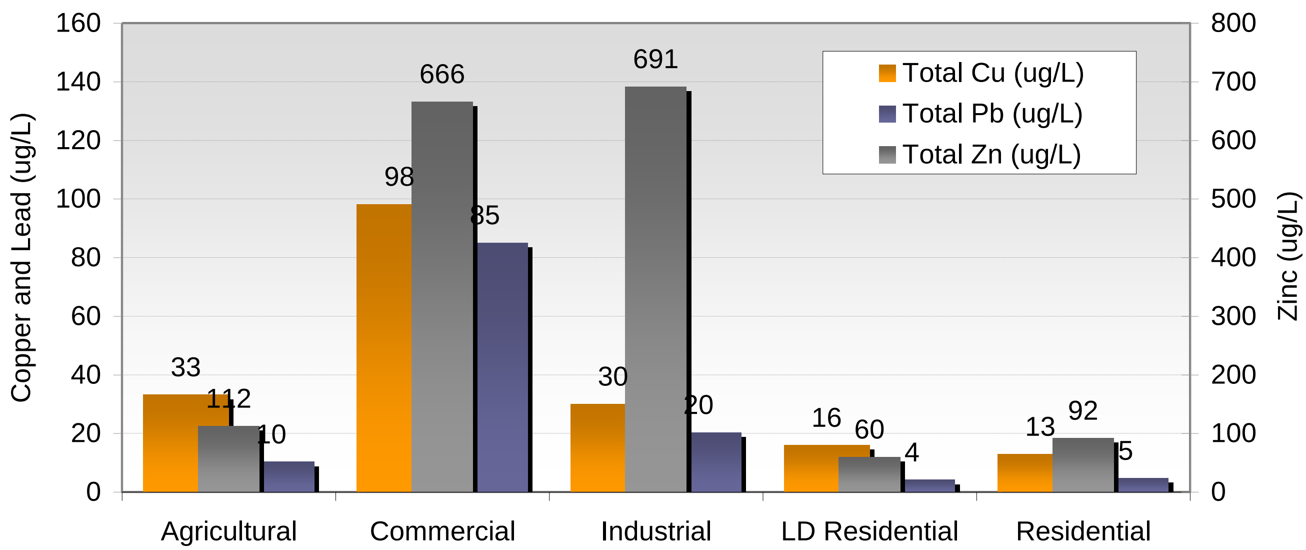


Figure 7. Total Cu, Pb and Zn concentrations (µg/L) by land use category.

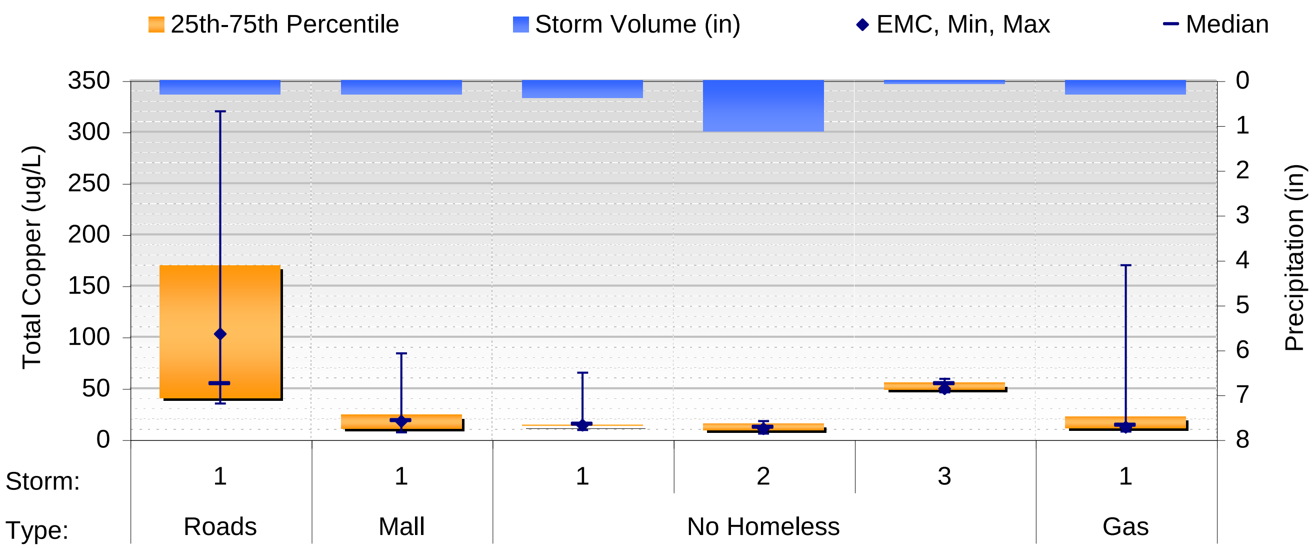


Figure 8. Commercial land use monitoring sites summary for Total Cu (µg/L).

Fecal Coliform

Overall, agricultural land uses have the highest levels of fecal coliform, followed by commercial land uses, as shown in Figure 9. One site where horses were present, as shown in Figure 10, tended to have higher levels of fecal coliform bacteria. Even low-density urban residential areas appear to be potentially high sources of fecal coliform bacteria, especially during high rainfall runoff events, as shown in Figure 11.

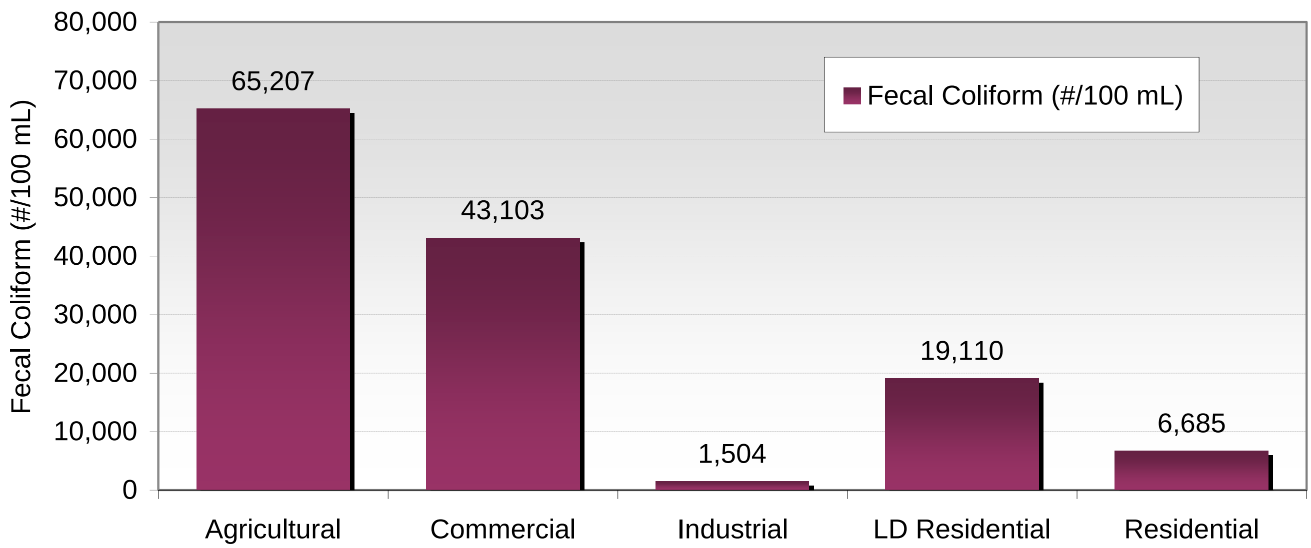


Figure 9. Fecal coliform counts (#/100mL) by land use category.

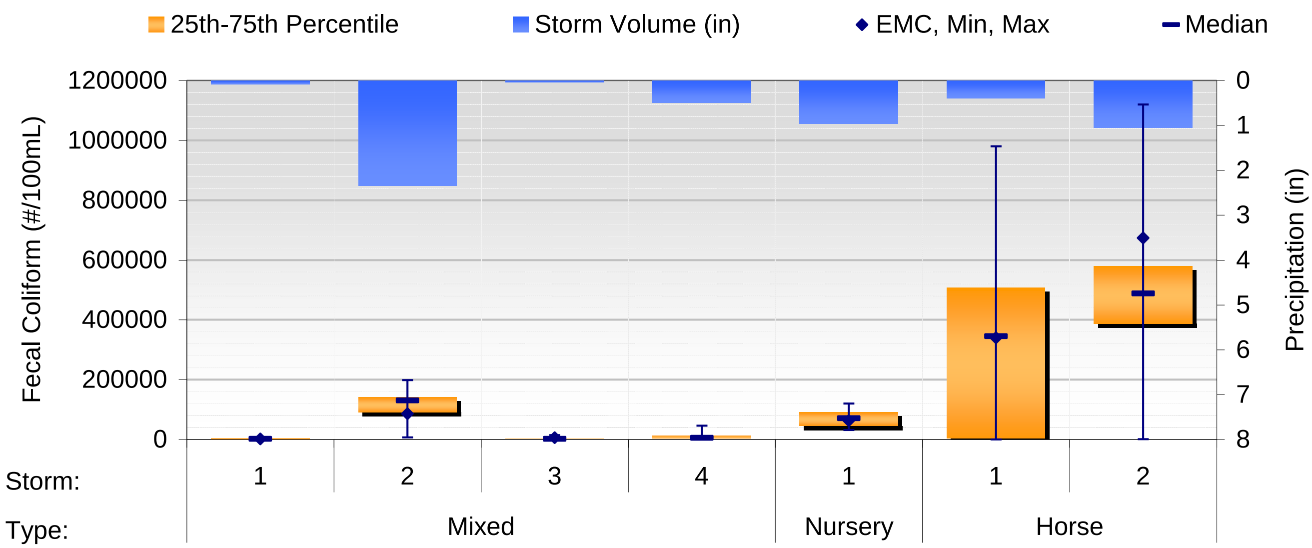


Figure 10. Agricultural monitoring sites summary for fecal coliform (#/100mL).

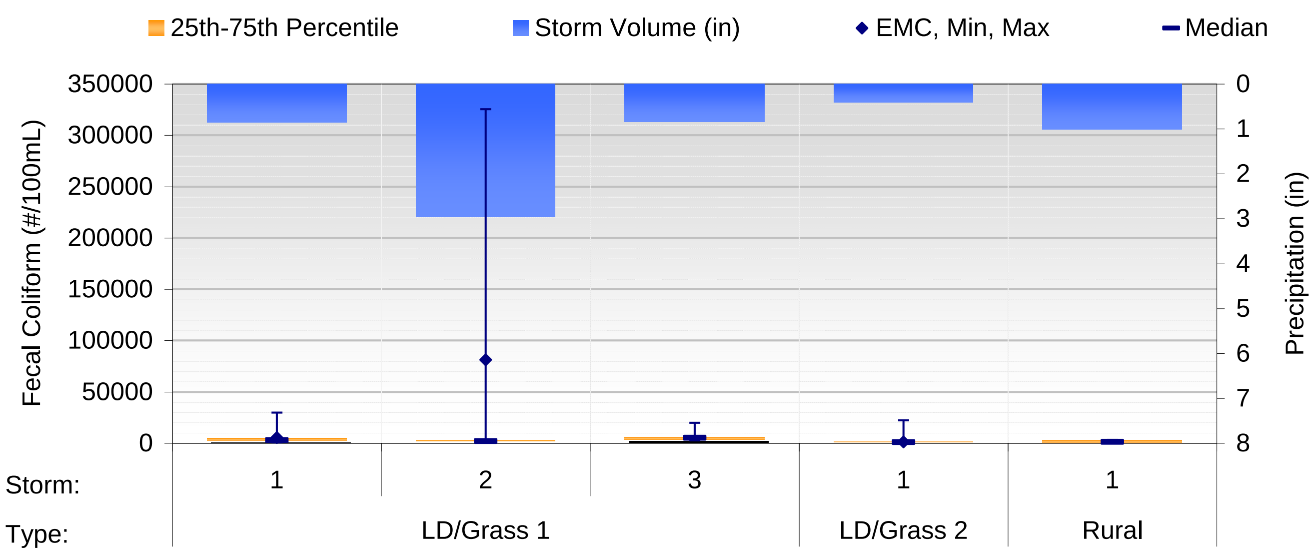


Figure 11. Low-density residential land use monitoring sites summary for fecal coliform (#/100mL).

Water Quality Calibration

The water quality calibration was developed on the basis of building and testing a parameter set for land use-specific pollutant load predictions. The overall calibration and validation approach includes the following steps:

1. Calibrate
    a. Vary parameters to develop best fit HRU/EMC responses for individual land use sites
    b. Add in-stream point source load contributions and hydromodification

2. Validate: Evaluate responses at downstream mass emission locations for a combined model using a fixed parameter set

The calibration steps were applied first for sediment, followed by water- and sediment-associated pollutants.

Sediment Calibration

Several of the pollutants of concern move sorbed to sediment, so accurate sediment simulation is an important step in water quality modeling. Sediment calibration follows the hydrology calibration and precedes the water quality calibration.

The parameters that define sediment generation and transport comprise those parameters required to numerically describe splash detachment of the soil matrix by rain drops, surface accumulation of sediment from anthropogenic sources, washoff of the detached sediment, scour of the soil matrix by overland flow (gullying), and sediment transport in the stream channel.

The sediment calibration discussed here builds upon the regionalized parameters developed by SCCWRP (Ackerman and Weisberg 2006).

Pervious Lands

The original SCCWRP regional sediment approach assumed that the pervious land sediment erosion parameters are the same for all pervious land segments. For most of the urban land areas, that assumption is probably acceptable because the urban soils are generally poor-draining soils that behave similarly. However, for the vacant areas, which account for 73 percent of the total *pervious* land area in the county (58 percent of the total land area), the assumption overlooks the differences in soil characteristics, slope, or rainfall intensities in the region.

The sediment calibration is based on varying key parameters in the LSPC model including

- KRER: Sediment Detachment Coefficient
- JRER: Exponent of Detachment Equation
- KSER/JSER: Overland Flow Depth/Exponent

The expected range for the sediment detachment coefficient KRER is 0.10 to 0.35. The original SCCWRP regionalized estimate for KRER was 0.35. That value was reasonable as a generalized estimate, because the original set of parameters did not differentiate between steep or moderate slopes. For refinement of the model KRER values were varied to reflect differences in soil erodibility and slope. The larger KRER values were assigned to steep slopes, while lower KRER values were assigned to moderate slopes.

Because the Richardson model of erosivity suggests using a value of 1.81—rather than the commonly used value of 2.0—for the exponent of the detachment equation, JRER, that parameter was updated to 1.81 for all pervious HRUs.

Sediment yield to streams depends on both rates of detachment and transport capacity of overland flow. At many times, it is transport capacity rather than sediment detachment that limits yield. The transport capacity is determined by parameters KSER and JSER, where KSER is a multiplicative factor on overland flow depth and JSER is an exponent, usually set to 2.

KSER is usually determined solely through calibration; however, the *possible range* cited by USEPA (2006b) is 0.01 to 5.0. Previous models had used KSER values of 8, clearly outside that range. New lower values for KSER have been developed through calibration that fall within the recommended range.

The previous SCWRRP regional sediment approach did not address sediment load from gullying. In keeping with that, the current model also sets the load source to zero.

Impervious Lands

Sediment generation and transport from impervious areas has generally not been given as much attention as sediment erosion from pervious lands. In many watershed model applications, that is appropriate because pervious lands usually compose the vast majority of the modeled areas. For LA County, impervious areas are a significant portion of the total area, and the areas have been shown to contribute loads of suspended solids that are monitored as sediment in the streams. Furthermore, metals and other toxics are bound to the solid particles originating from those impervious urban areas.

For impervious areas, the accumulation and removal of solids by runoff and other means is the modeled process. ACCSDP is the accumulation rate of solids, while REMSDP is the unit removal rate of solids when there is no runoff. Most of the land uses in the SCCWRP regional parameter set had ACCSDP values of 0.004. According to EPA's *BASINS Technical Note 8: Sediment Parameter and Calibration Guidance for HSPF*, data from street surfaces suggest values of ACCSDP in the range of 0.0005 to 0.1, with most data in the range of 0.001 to 0.02 (USEPA 2006b). That calibration suggests that a value of 0.001 fits the results better.

REMSDP is the unit removal rate of solids when there is no runoff. That parameter can be modified to account for street sweeping. Most of the impervious land uses in the regional parameter set have REMSDP values of 0.025. *BASINS Technical Note 8* recommends values for REMSDP in the range of 0.001 to 0.1, with typical values in the range of 0.001 to 0.07. The ranges suggest that the SCCWRP regional REMSDP value of 0.025 for most impervious land uses is appropriate. A value of 0.025 for all impervious areas was chosen for REMSDP.

The parameters KEIM and JEIM are used in the washoff equation to calculate the transport capacity. KEIM is the coefficient of transport, while JEIM is the exponent for transport. The mass of solid particles that washes off is directly dependent on the amount of surface runoff.

KEIM is the primary calibration parameter for solids transport from impervious surfaces. That parameter relates transport capacity to flow depth and combines the effects of slope, overland flow length, sediment particle size, and surface roughness on the sediment transport capacity of overland flow into a single parameter. Washoff potential was evaluated together with the accumulation and removal component to better understand their interaction for transporting solid particles. After performing that evaluation, updated values for KEIM were developed for the impervious HRUs. The calibrated KEIM values were much lower than what was used in previous modeling efforts.

In-stream Behavior

The in-stream sediment transport model is driven by sediment originating from the watershed and particles discharged from point sources. The sediment originating from the watershed is modeled as total sediment mass per time step. Sediment from the land is divided into three particle size bins for sand, silt, and clay. Occasionally, trapping factors are applied to the total sediment load before it is split into particle size bins to account for transport losses as particles travel from the edge-of-field to the stream itself. Table 7 is a summary of trapping factors and the sediment/solids size class distribution used in the model.

Table 7. Trapping factors and sediment/solids size class distribution used in the regional model

Percent trapped	Sediment/solids size class distribution		
	Sand	Silt	Clay
0%	5%	55%	40%

The stream sediment transport module for this application was parameterized with consistent sediment/solids size class distributions, and consistent sediment transport variables for all subbasins.

Sediment Parameters Conclusion

A *systematic* calibration approach was performed to develop the parameter set that provided the best fit with the available data. The goal of the calibration process was to keep the number of unconstrained *calibration* parameters at a minimum while following a standard operating sequence for model fitting. The land use representation and parameterization was standardized across all areas so that the associated parameters can be truly representative of a regionalized model for the county watersheds.

Unless there were clear, indisputable data to differentiate among land uses, the impervious upland parameters were kept the same. In this case, the same value of JEIM, ACCSDP, and REMSDP were not changed for all impervious lands, and only KEIM was changed to account for loading magnitude differences. For pervious lands, KRER values were changed only dependent on slope characteristics, and KSER was used as the primary calibration variable.

Water Quality Parameters

The goal of the regionalized approach to water quality calibration was to select water quality parameters that would adequately represent the loading generation capabilities for the different modeled HRUs for a wide range of storm intensities.

The removal of sediment-associated water quality constituents by sediment washoff is simulated by multiplying the washoff of detached sediment (tons/acre/time interval) times the parameter POTFW. POTFW is the washoff potency factor (quantity/ton). POTFW describes the amount of a water quality constituent that is associated with a ton of sediment for a land segment. The original SCCWRP regional parameter set defined different POTFW parameter values for Cu, Pb, and Zn by land use.

For this calibration, a potency factor analysis was performed using available storm sampling data. To estimate the potency factors, mass- and flow-weighted concentrations were used to calculate the ratio between the metals and the sediment by land use. The derived values were then compared to previously estimated potency factors as shown in Table 8. Four of the values were selectively updated on the basis of further review of the SCCWRP land use monitoring data summarized Table 6. The ratio of metals to sediment for the flow-weighted average concentrations at each site were computed. The ones that were slightly outside the range of observed variation were adjusted to better fit the summarized data. Many of the values were unchanged. The four that were changed are shown in parentheses in Table 8 beside the original values.

Table 8. Land use-specific washoff potency factor (POTFW) parameter values for trace metals used in previous SCCWRP models (updated values shown in paremtheses)

Land use[a]	Trace metal		
	Cu (lb/ton)	Pb (lb/ton)	Zn (lb/ton)
AGR	0.30	0.10	2.50
COM	1.00 (1.14)	1.00	10.20
HDR	0.80	0.80	7.50
IND	0.30 (0.4)	0.15 (0.18)	4.00 (5.08)
LDR	0.60	0.20	1.20
MIX	0.80	0.25	5.00
OPEN	0.12	0.02	0.50

Source: SCCWRP 2004
Note:
a. AGR = agriculture; COM = commercial; HDR = high-density residential; IND = industrial; LDR = low-density residential; MIX = mixed urban; OPEN = open.

An initial value of POTFW was selected from that table for each of the HRU/pollutant combinations. A systematic process was developed to select the most reasonable water quality parameter values. The process entailed calculating the EMC for each pollutant of concern for each of the monitored storms by land use site. The result was compared with the modeled EMC for the same storm, pollutant, and site combination. If the modeled EMC was too low, the associated POTFW was increased accordingly. If the POTFW was as high as the monitoring data analysis indicated, an additional surface concentration (SOQC) of pollutant was added that was not related to sediment. If the modeled EMC was too high, the POTFW was reduced accordingly.

The following section provides a summary of the resulting calibration for each predominant HRU, including a map of the calibration site, a pie chart showing area distribution, and average modeled EMC versus observed EMC and interquartile concentration ranges. Because of the large number of individual storm responses at each site, only the aggregated summary modeled versus observed EMCs are shown here (for TSS, Cu, and fecal coliform). The full set of calibration summaries are in Appendix B. The actual time series responses for each storm at each monitoring location are compiled and presented in Appendix C. In-stream modeled versus observed time series graphs are shown for each mass emission stations as part of the model validation. The calibration graphs provide an assessment of the predictive ability of the model over a range of hydrologic conditions. The parameters were selected to achieve a good fit across the range of conditions simulated. Variability in fit can be based on multiple factors including localized storm conditions or antecedent conditions, localized sources, and rapid changes in the intensity of rainfall. Those factors can cause some storms or locations to fit better than others. The calibration process seeks to identify the parameters that will fit the broad range of conditions without systematic over or under prediction.

Residential HRU Calibration

LU01 Residential HD Mixed is mostly composed of multifamily and high-density single family residential impervious areas and their associated urban grass pervious components. It also includes a significant percentage of secondary roads. The monitoring site is in the Los Angeles River watershed. Figure 12 and Figure 17 are a Location/HRU map and a land use distribution chart, respectively, for site LU01, Residential-HD Mixed. Figure 18 through Figure 20 show aggregated summaries of modeled versus observed EMCs for TSS, Cu, and Fecal Coliform, respectively. In these graphs (and those in subsequent sections), the modeled EMC is plotted as an open circle on top of the box-and-whisker interquartile plots of observed concentrations.

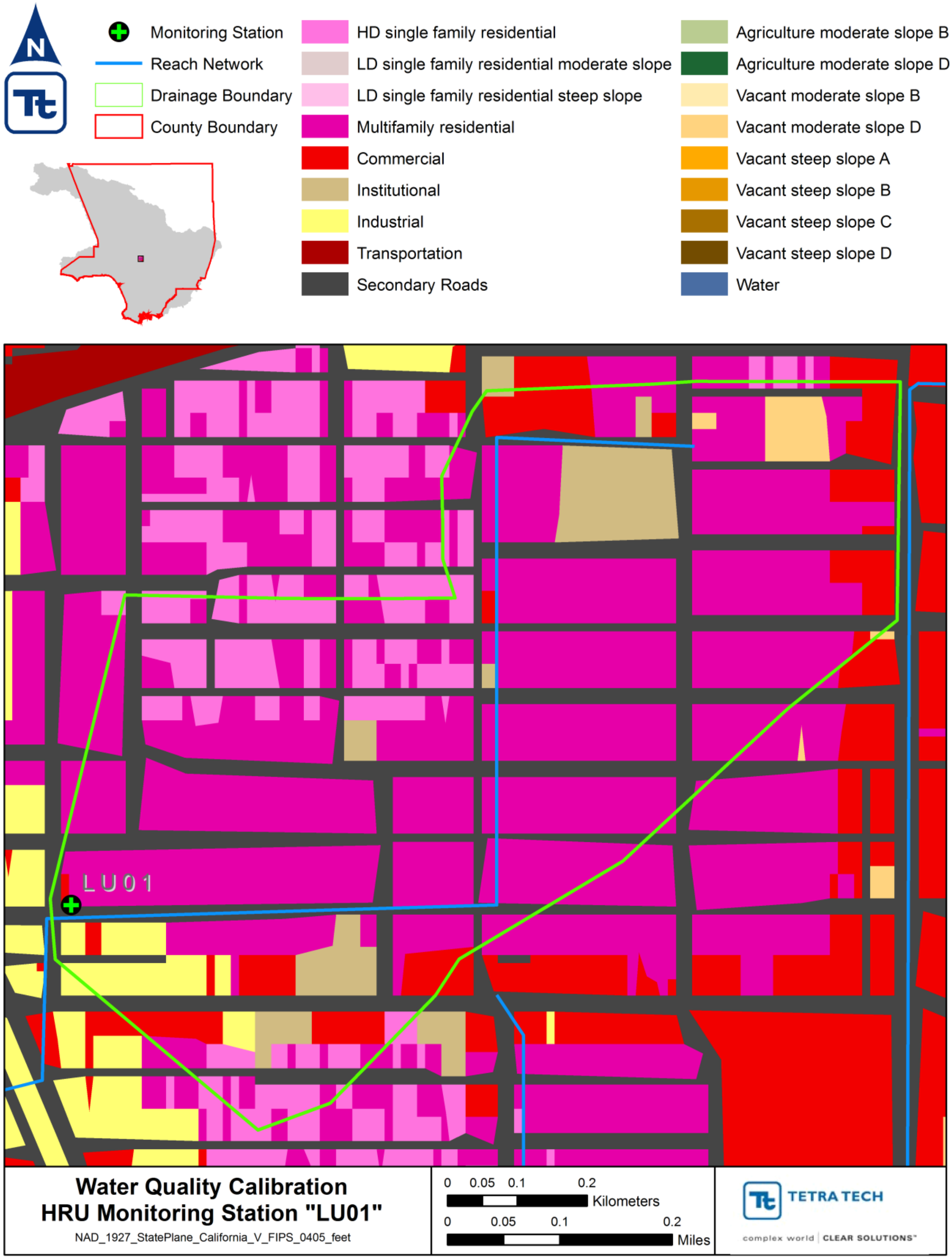


Figure 12. Location and HRU map of site LU01, Residential-HD Mixed.

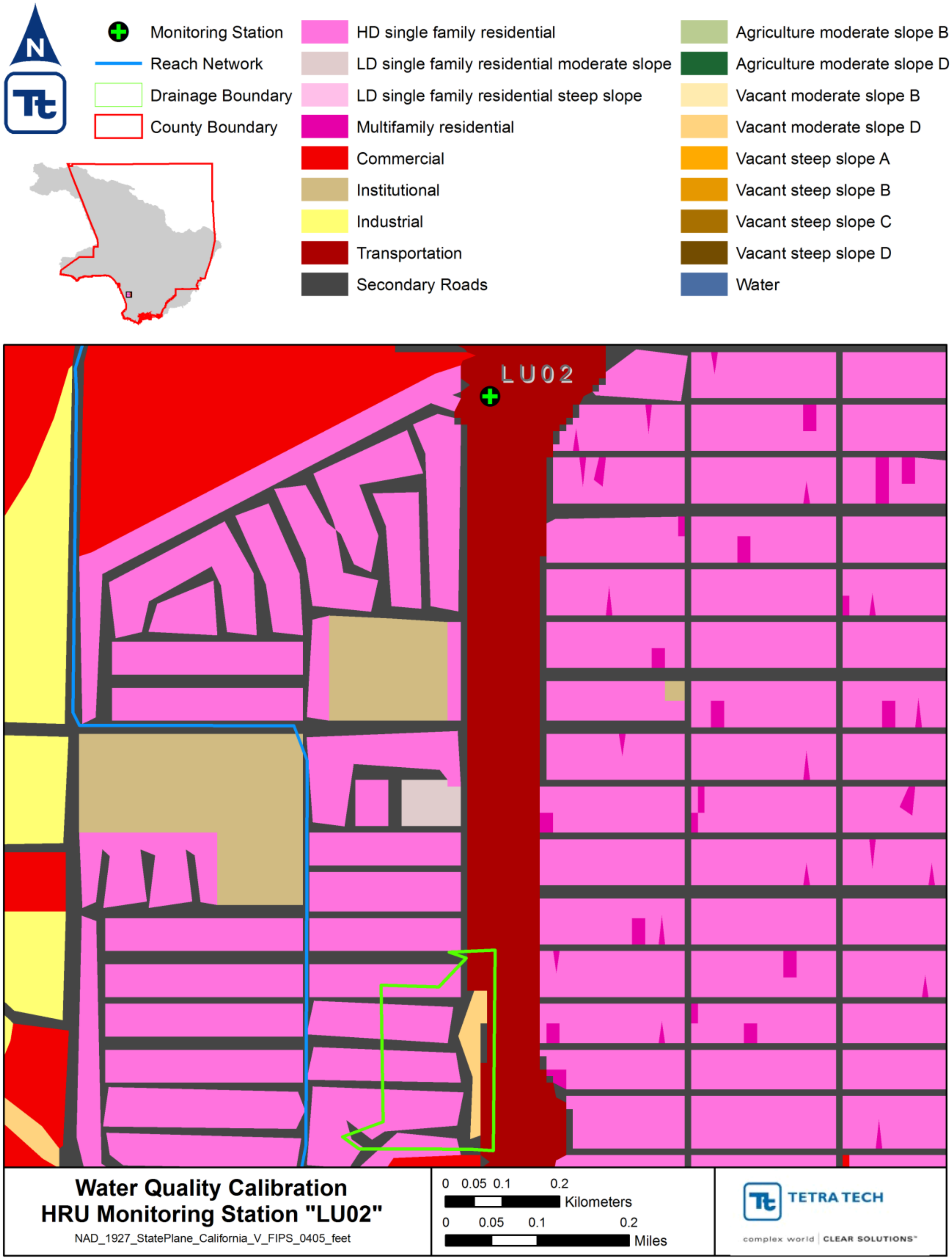


Figure 13. Location and HRU map of site LU02, Residential-HD Pets.

Figure 14. Location and HRU map of site LU25, Residential-HD.

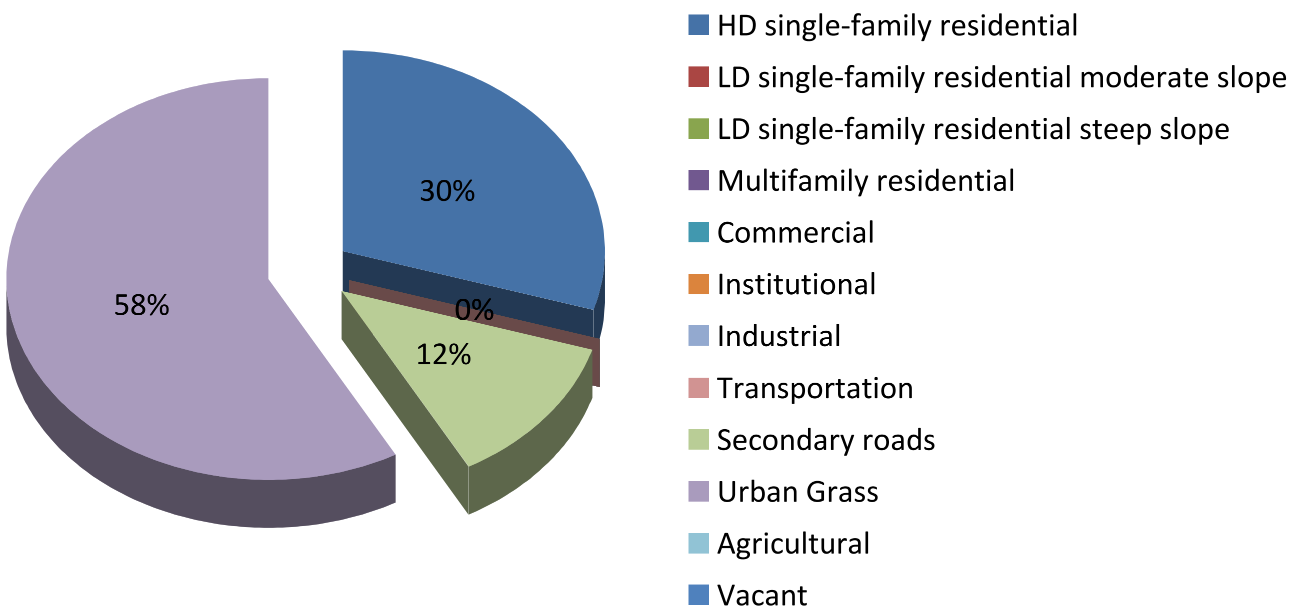


Figure 15. Land use distribution upstream of site LU25, Residential-HD.

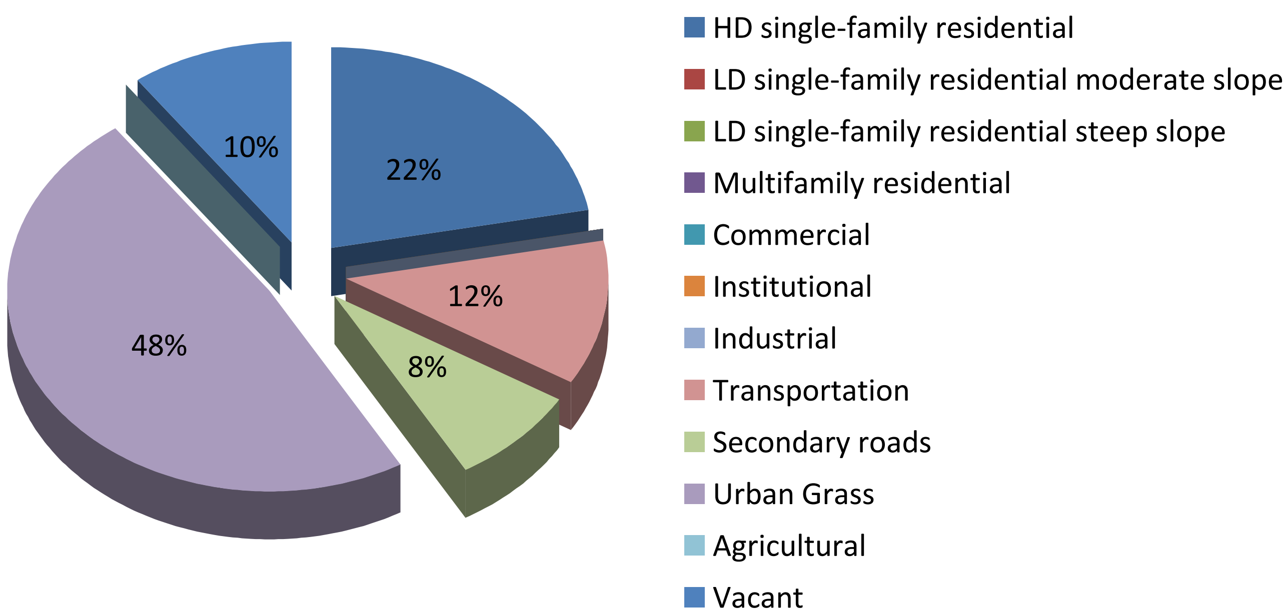


Figure 16. Land use distribution upstream of site LU02, Residential-HD Pets.

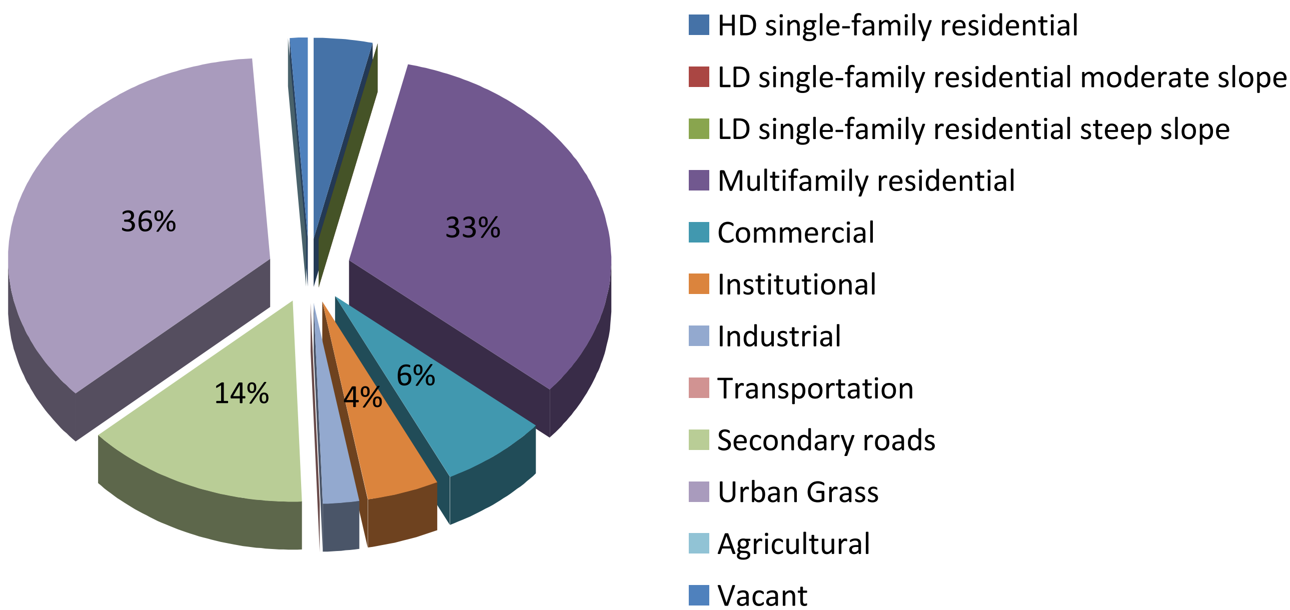


Figure 17. Land use distribution upstream of site LU01, Residential-HD Mixed.

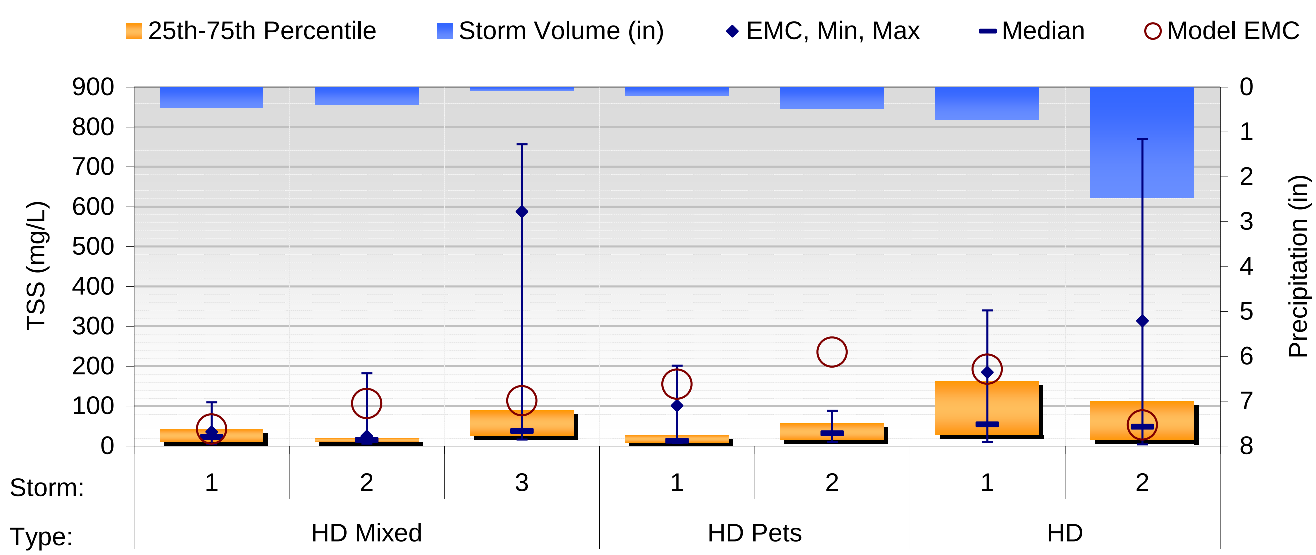


Figure 18. Residential land use monitoring sites summary for TSS (mg/L).

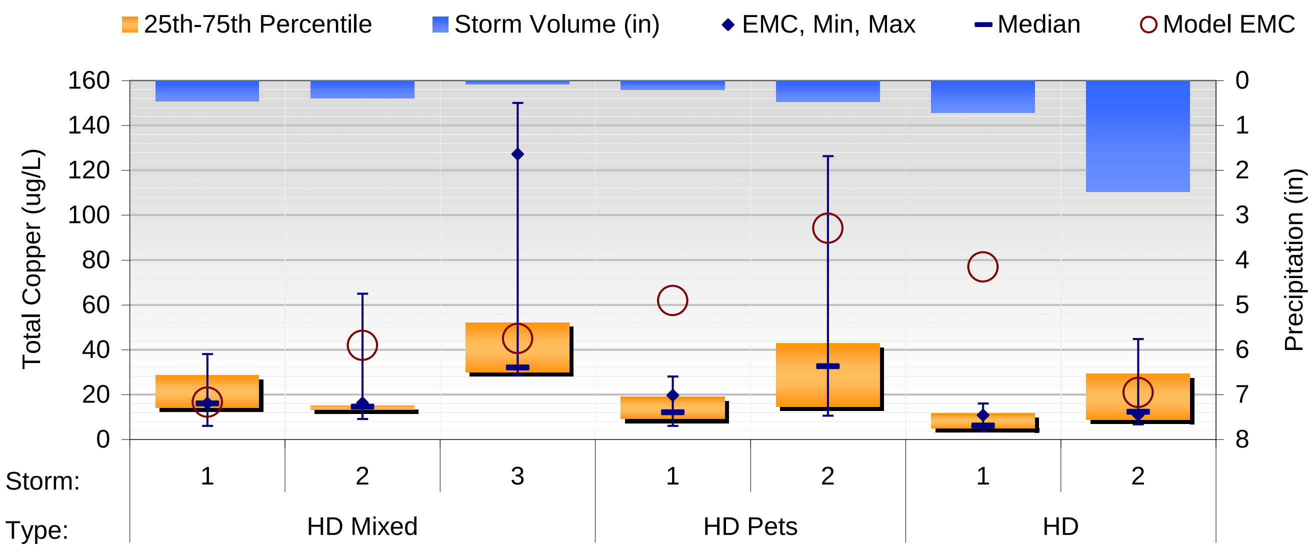


Figure 19. Residential land use monitoring sites summary for Cu (µg/L).

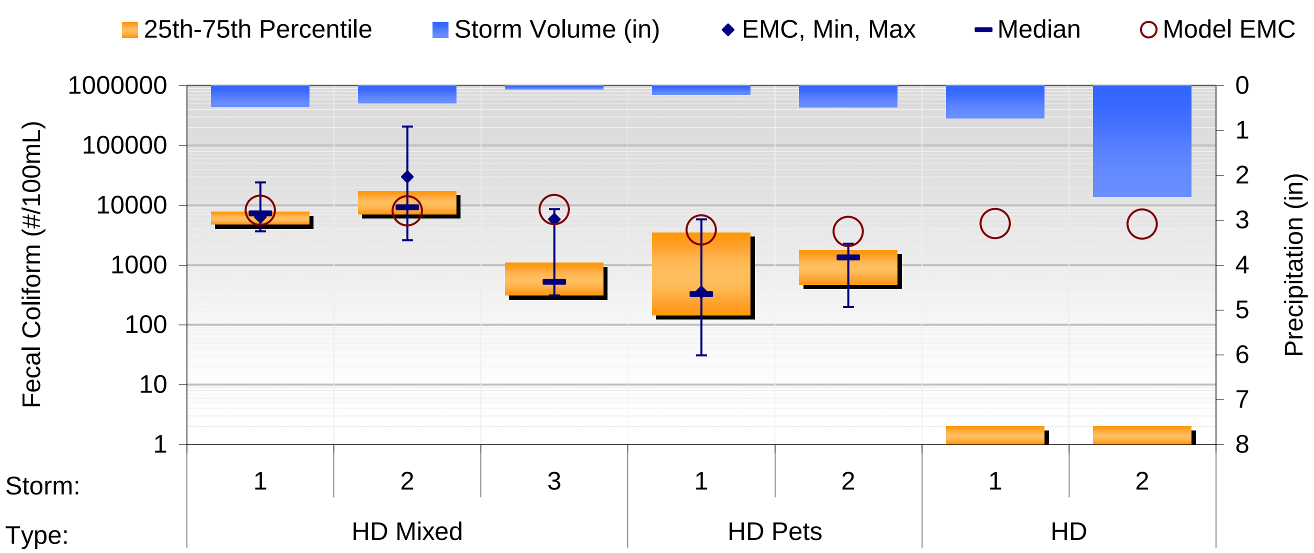


Figure 20. Residential land use monitoring sites summary for fecal coliform (#/100mL).

Low-Density Residential and Urban Grass HRU Calibration

LU03 LD Residential-LD/Grass 1 is mostly composed of low-density residential areas. Figure 21 and Figure 22 are a location/HRU map and a land use distribution chart, respectively, for site LU03, Low-Density Residential and Urban Grass.

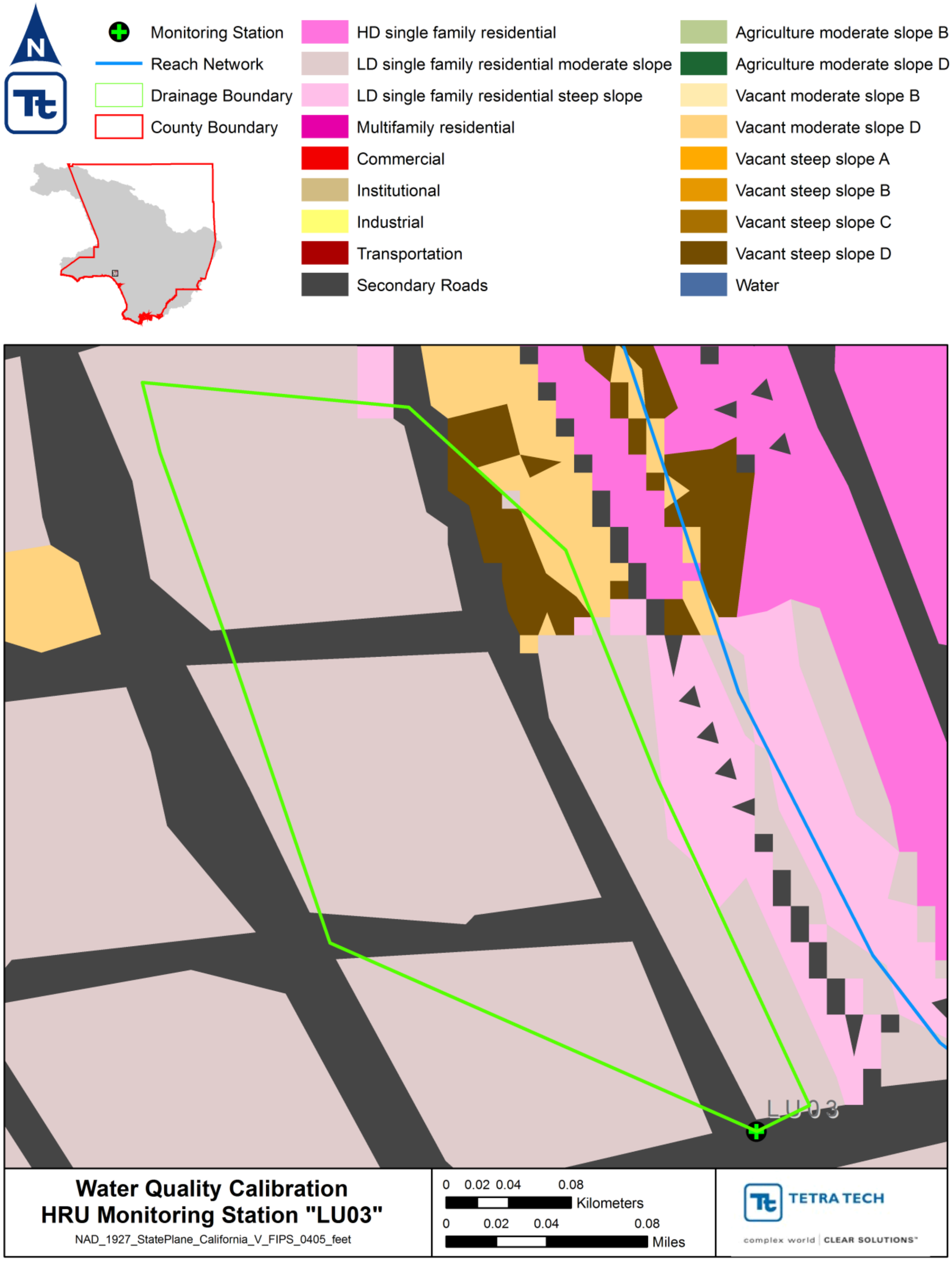


Figure 21. Location and HRU map of site LU03, LD Residential-LD/Grass 1.

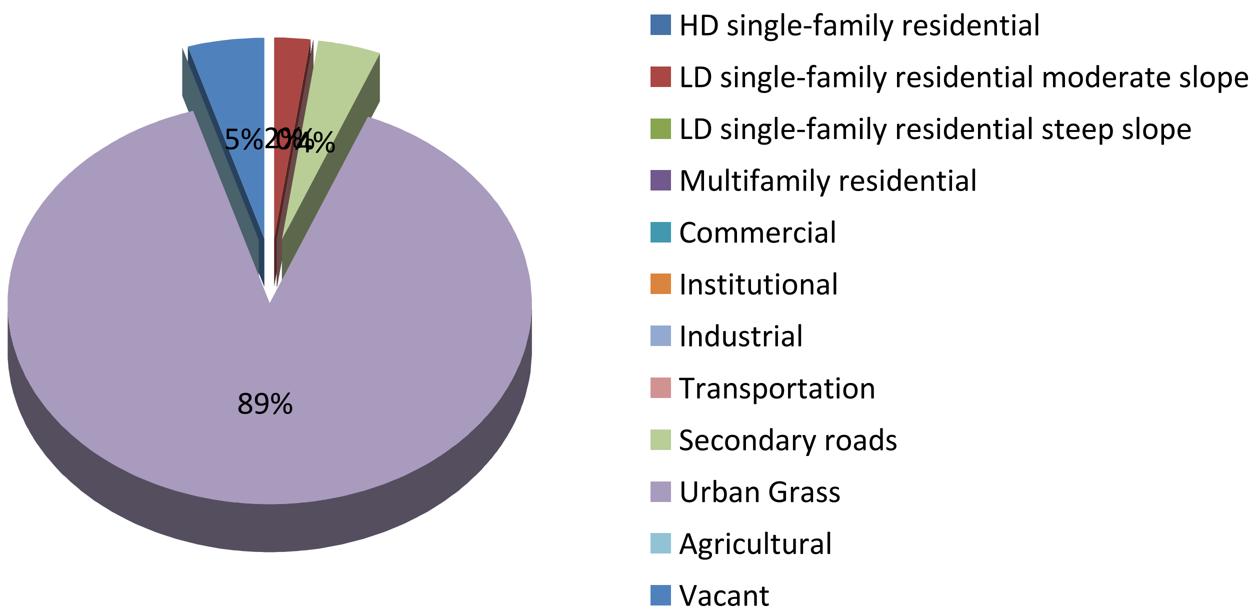


Figure 22. Land use distribution upstream of site LU03, LD Residential-LD/Grass 1.

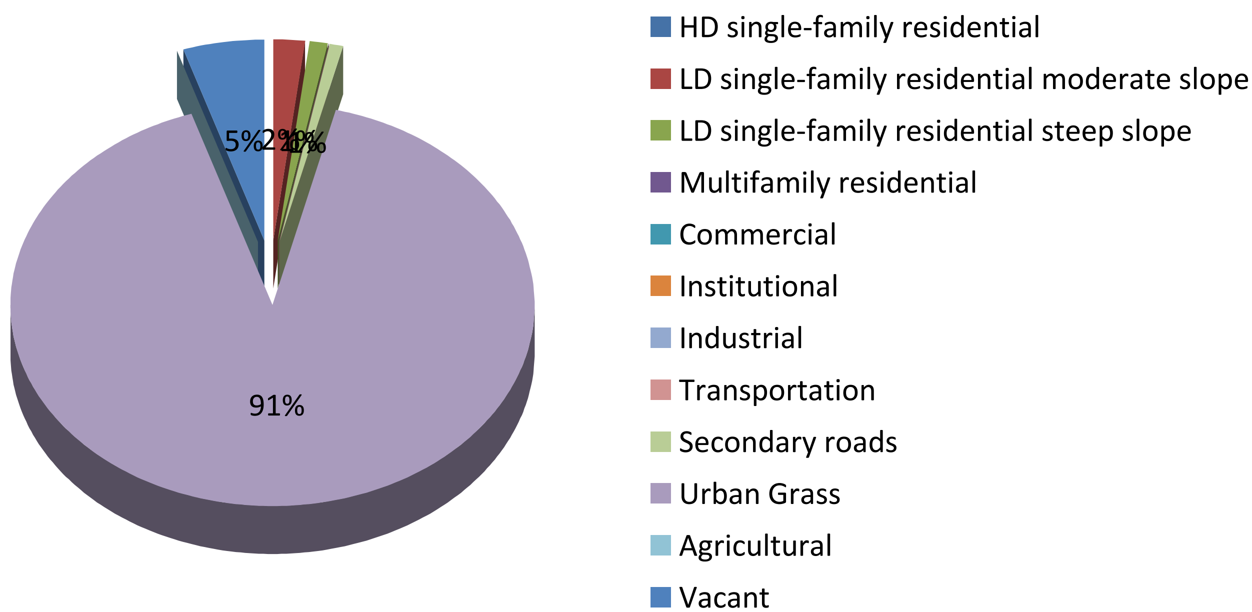


Figure 23. Land use distribution upstream of site LU04, LD Residential-LD/Grass 2.

LU03 LD Residential-LD/Grass 1 is mostly composed of low-density residential areas. Because the percent impervious of the low-density residential areas is low, most of the area is the urban grass that belongs to the low-density residential parcels. This site is in the Ballona Creek watershed.

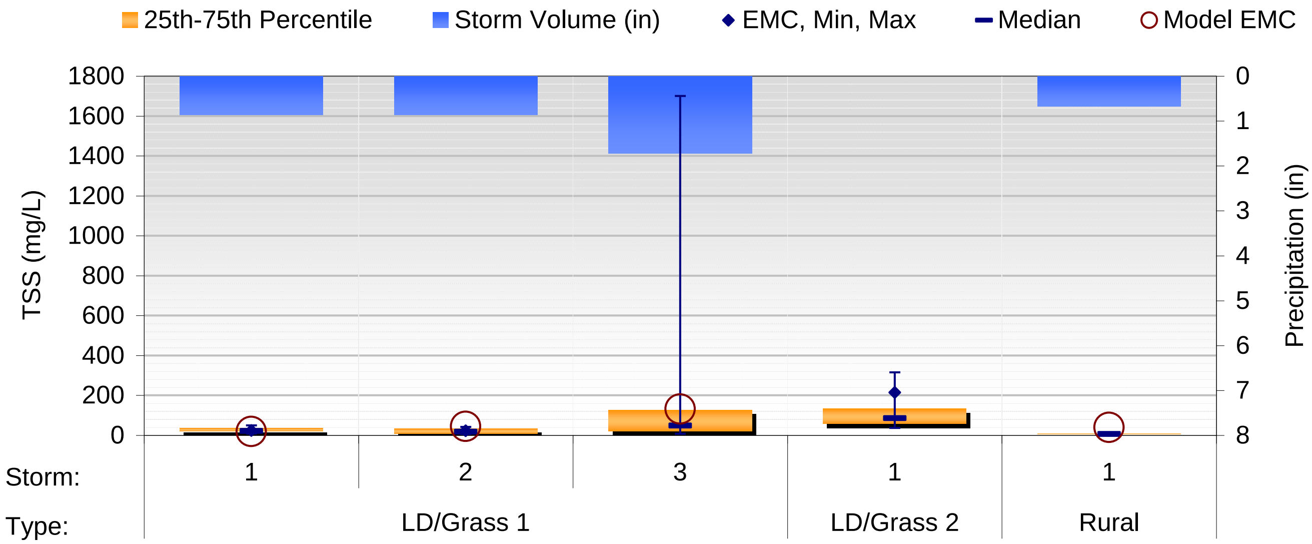


Figure 24. Low-Density Residential land use monitoring sites summary for TSS (mg/L).

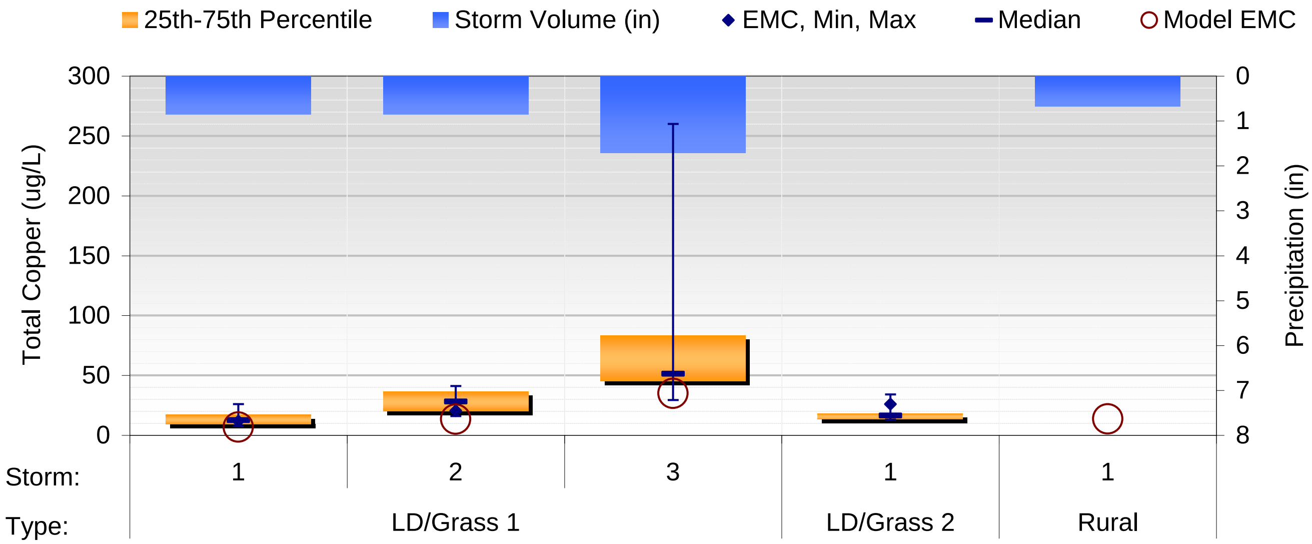


Figure 25. Low-Density Residential land use monitoring sites summary for total Cu (µg/L).

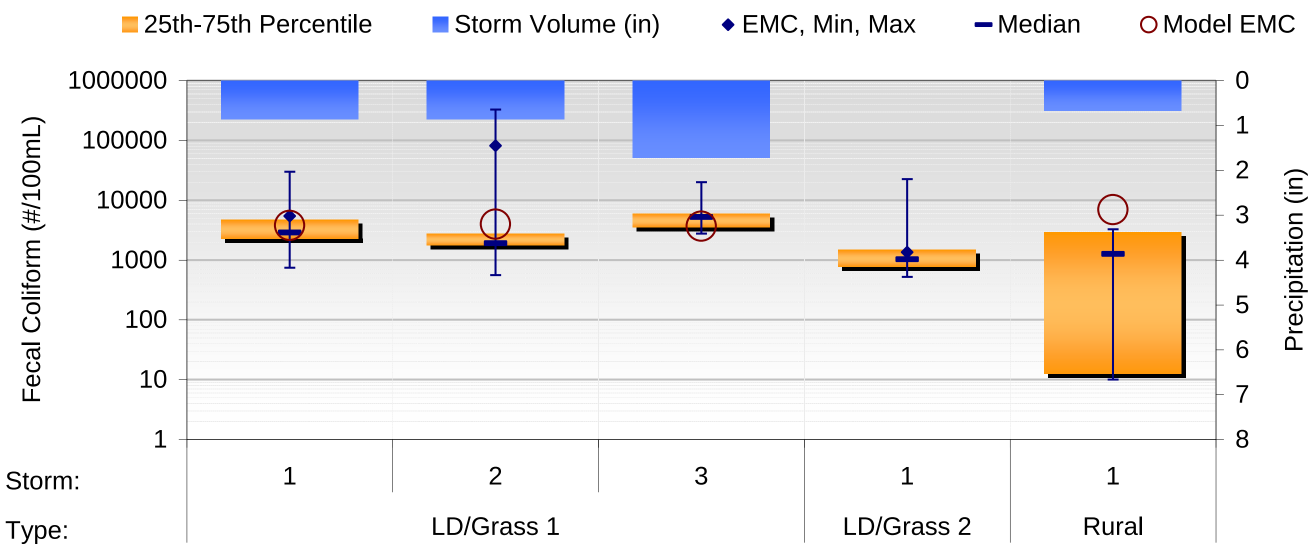


Figure 26. Low-Density Residential land use monitoring sites summary for fecal coliform (#/100mL).

Commercial HRU Calibration

LU06 Commercial roads (without homeless) is named as such because it has a high density of roads. Figure 27 and Figure 29 are a location/HRU map and a land use distribution chart, respectively, for site LU06, Commercial with roads.

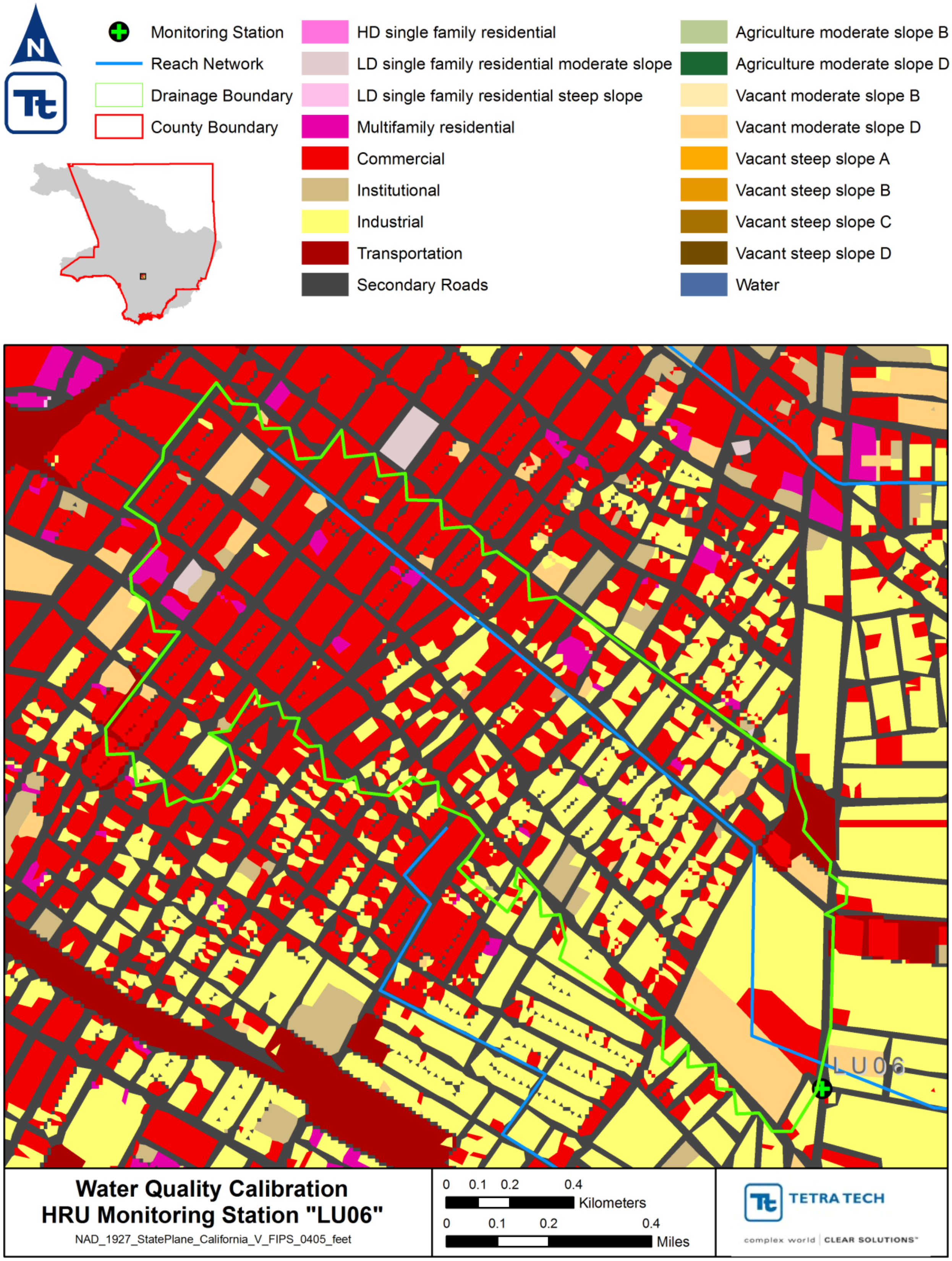


Figure 27. Location and HRU map of site LU06, Commercial-Roads.

Figure 28. Location and HRU map of site LU07, Commercial-Mall.

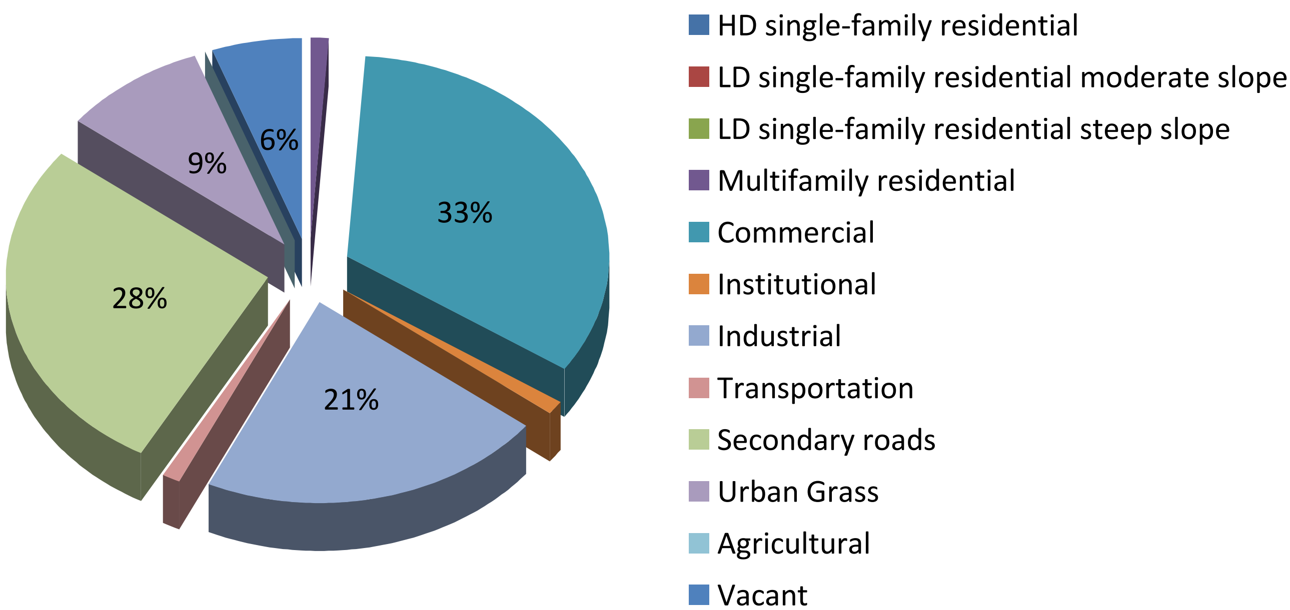


Figure 29. Land use distribution upstream of site LU06, Commercial-Roads.

The catchment area for site LU06 Commercial-Roads is a combination of commercial, secondary roads and industrial areas. The site is in the Los Angeles River watershed.

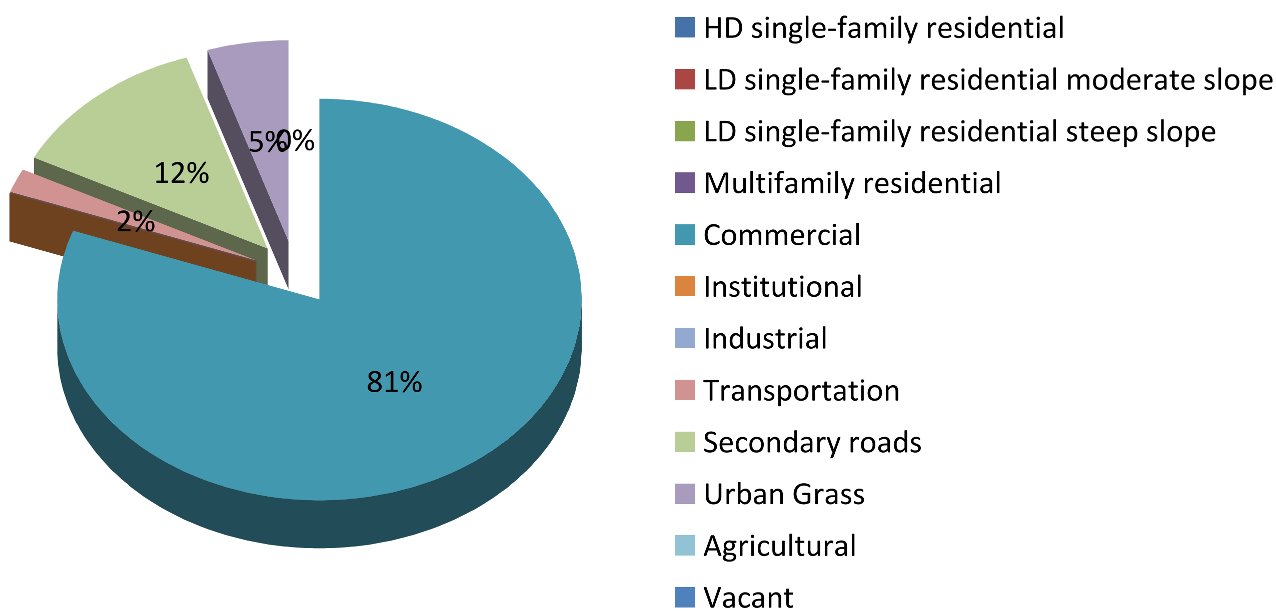


Figure 30. Land use distribution upstream of site LU07, Commercial-Mall.

The catchment area for LU07 is composed almost exclusively of commercial area. It is at a shopping mall in the Ballona Creek watershed.

Figure 31 shows the land use distribution for site LU08, Commercial w/o Homeless has a catchment area that is largely made of commercial areas. The second-most prevalent land use is industrial. This site is in the Los Angeles River watershed.

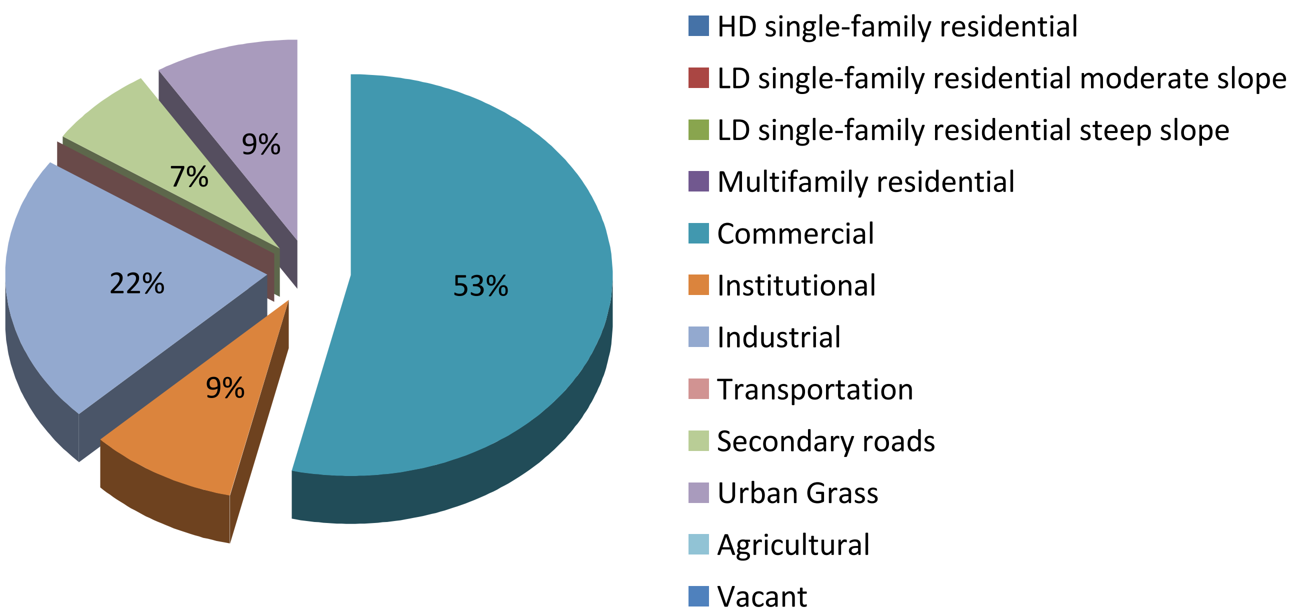


Figure 31. Land use distribution upstream of site LU08, Commercial w/o Homeless.

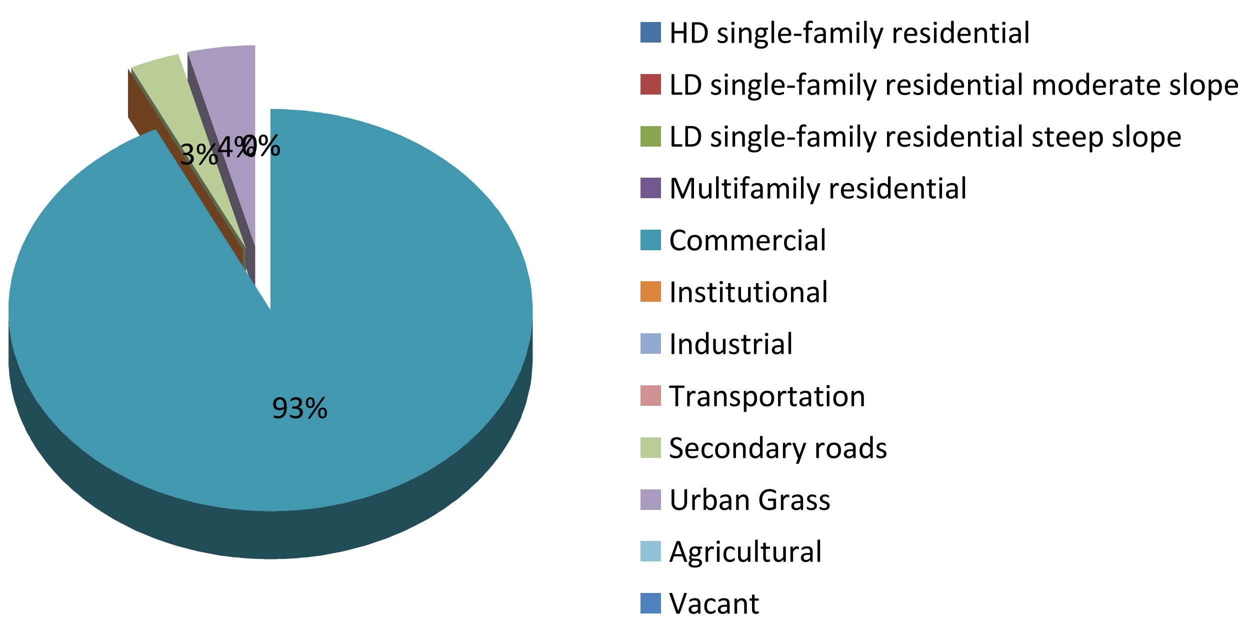


Figure 32. Land use distribution upstream of site LU20, Commercial-Gas.

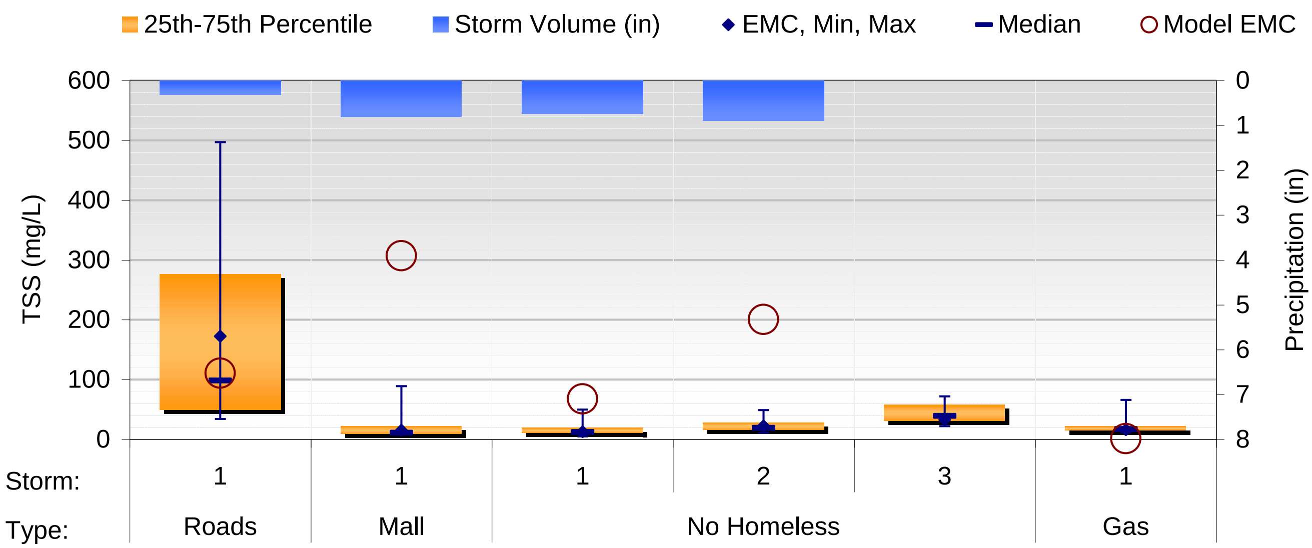


Figure 33. Commercial land use monitoring sites summary for TSS (mg/L).

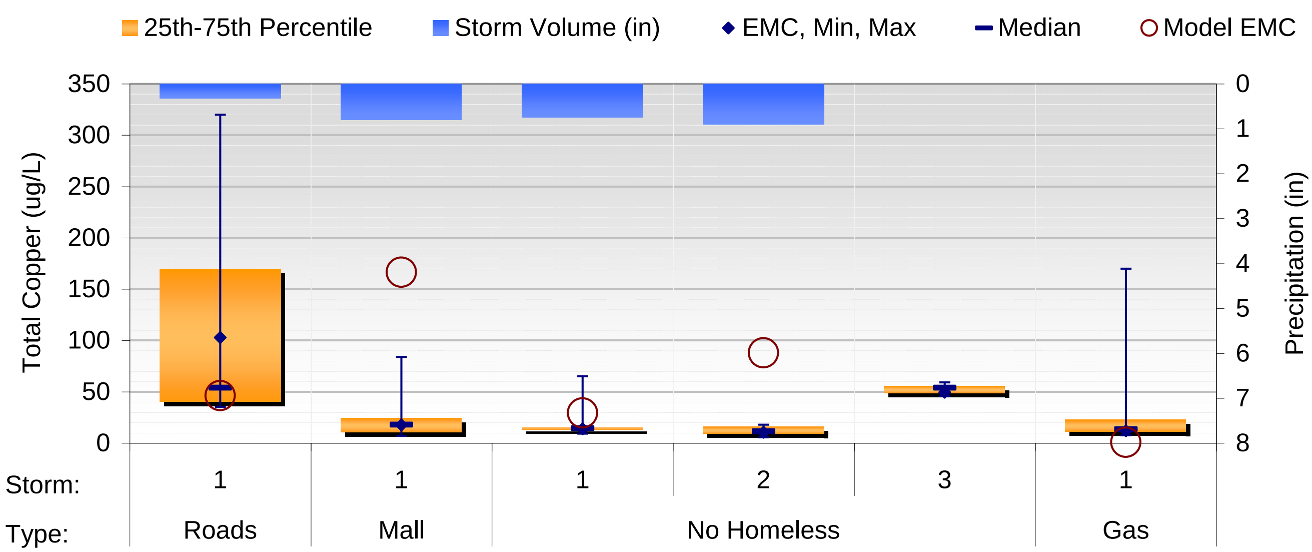


Figure 34. Commercial land use monitoring sites summary for total Cu (µg/L).

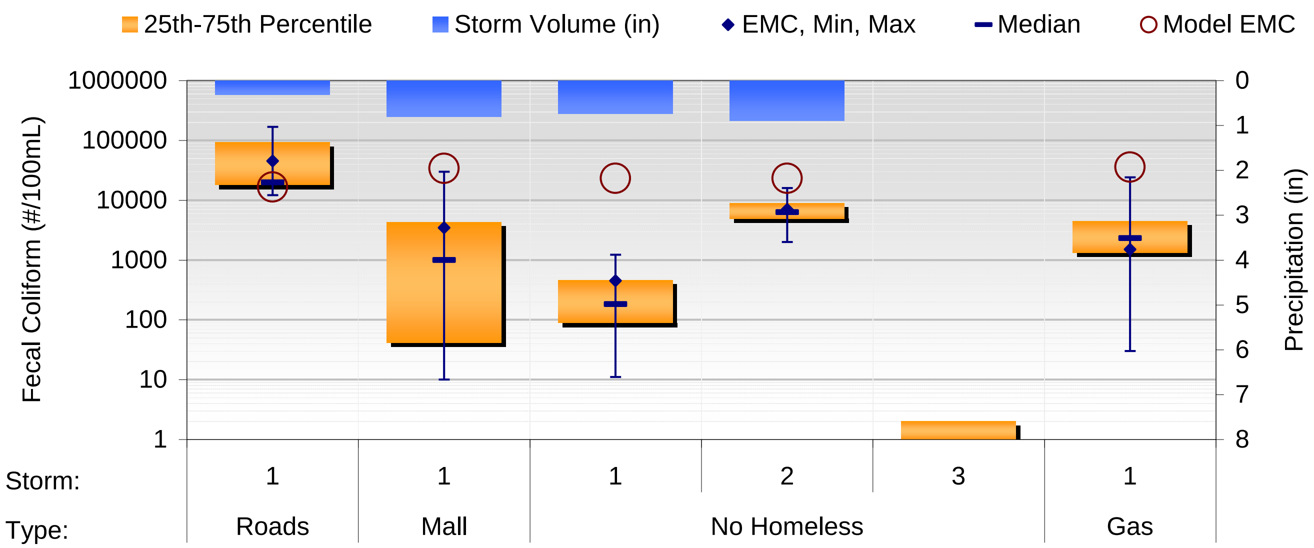


Figure 35. Commercial land use monitoring sites summary for fecal coliform (#/100mL).

Industrial HRU Calibration

Figure 36 and Figure 37 are a location/HRU map and a land use distribution chart, respectively, for site LU09, Industrial-Mixed.

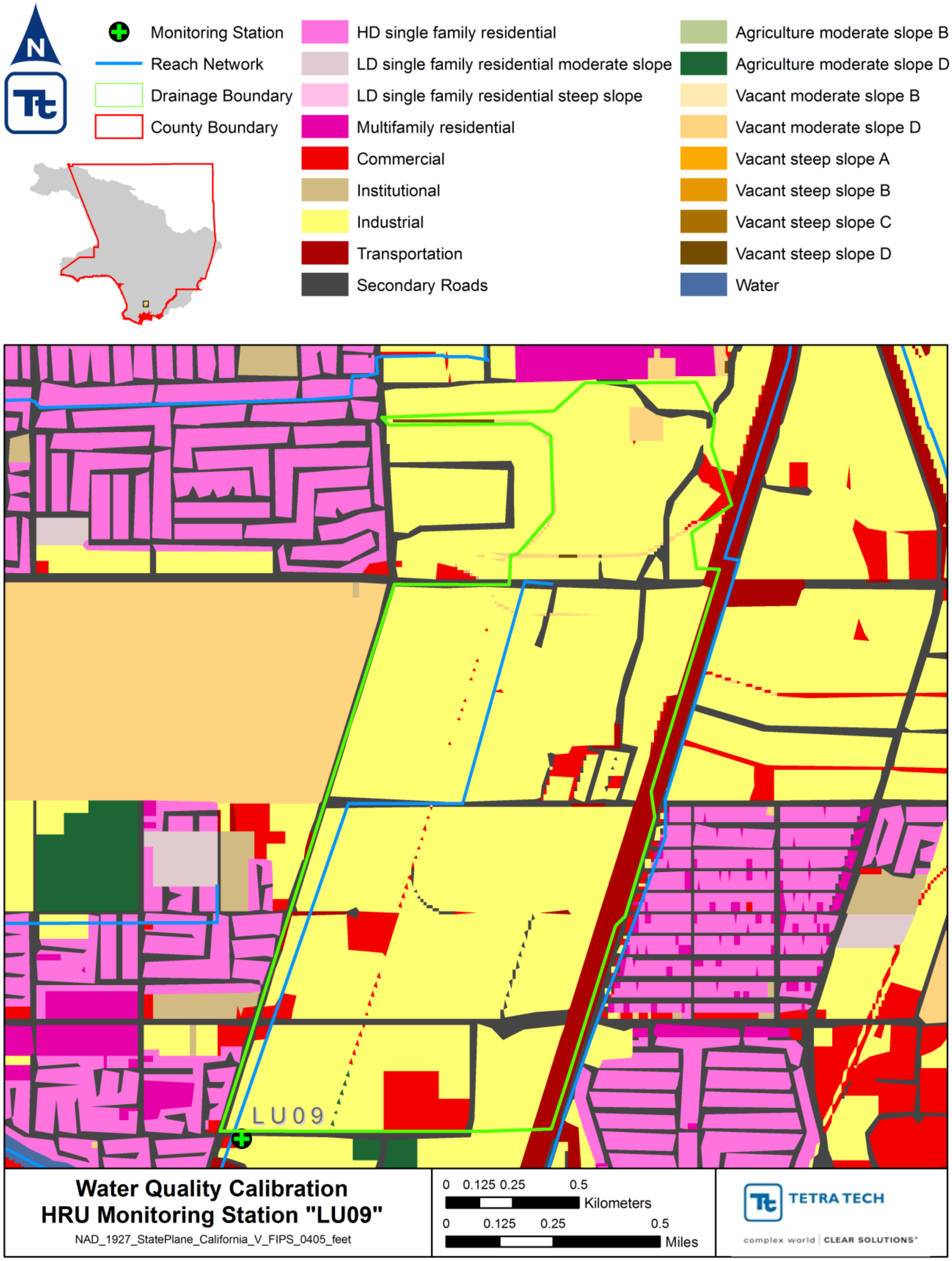


Figure 36. Location and HRU map of site LU09, Industrial-Mixed.

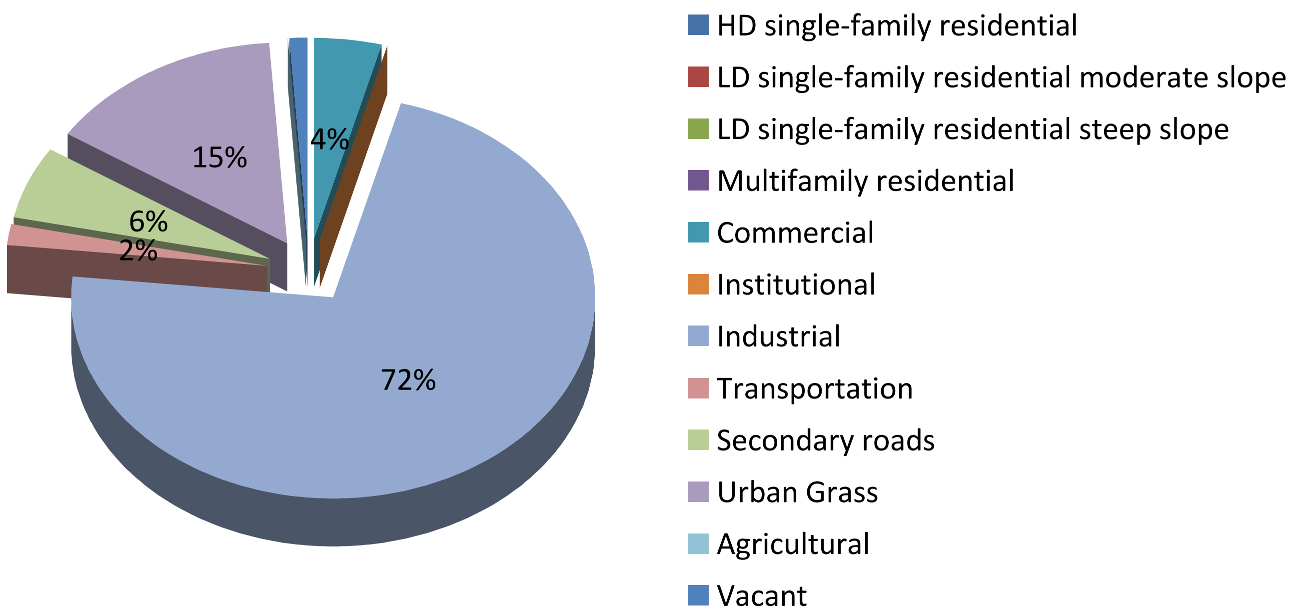


Figure 37. Land use distribution upstream of site LU09, Industrial-Mixed.

The drainage area for monitoring site LU09 Industrial Mixed is mostly industrial. It is in the Dominguez Creek watershed.

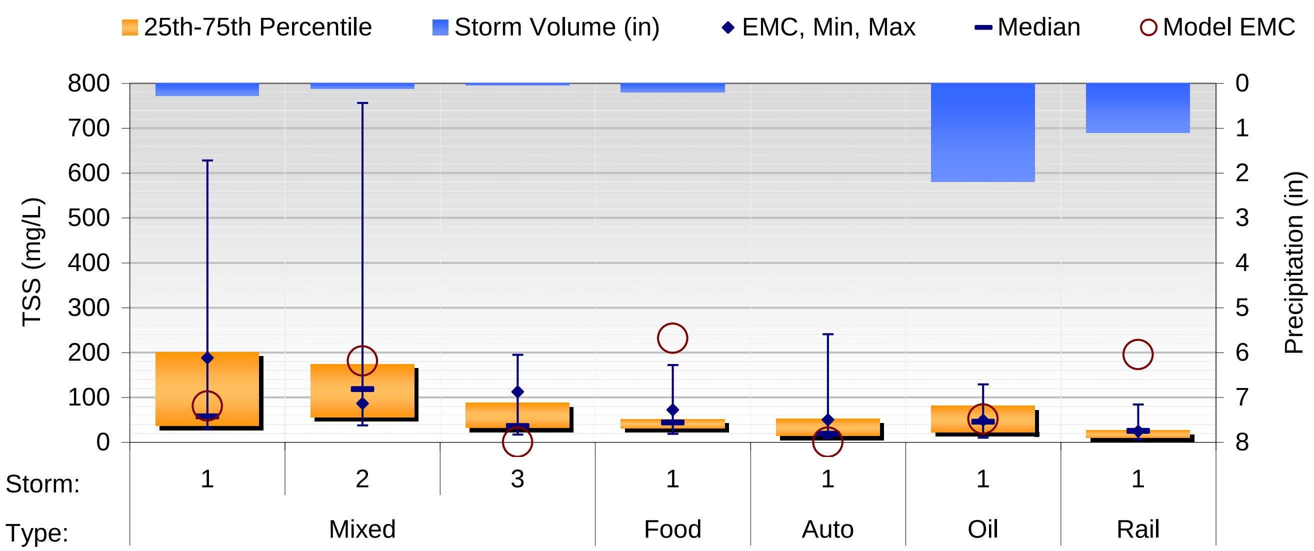


Figure 38. Industrial land use monitoring sites summary for TSS (mg/L).

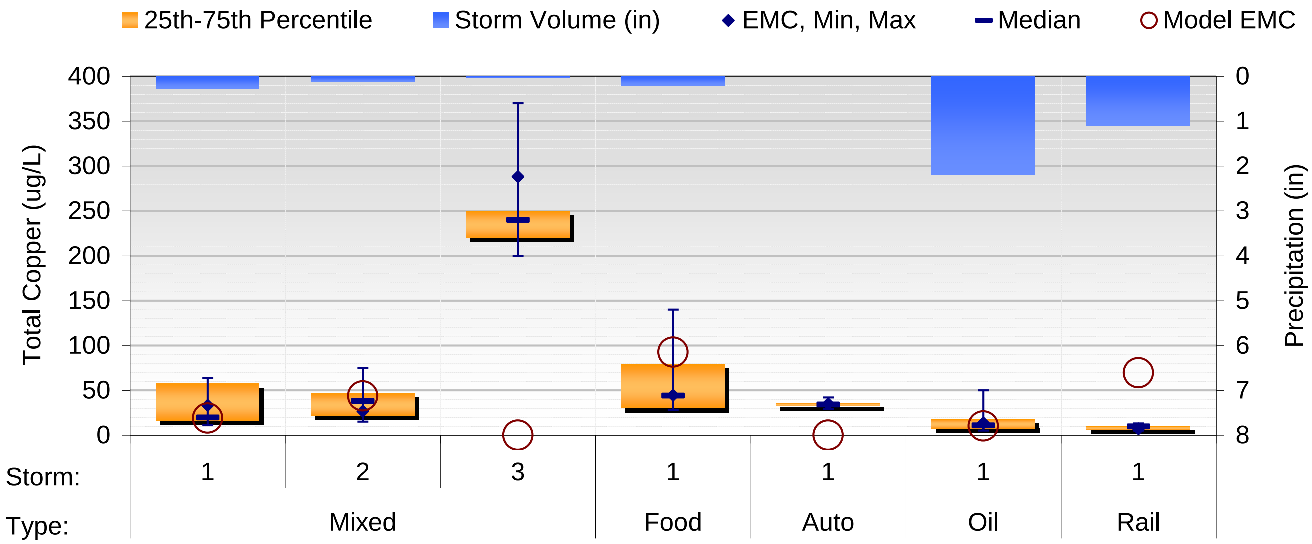


Figure 39. Industrial land use monitoring sites summary for total Cu (µg/L).

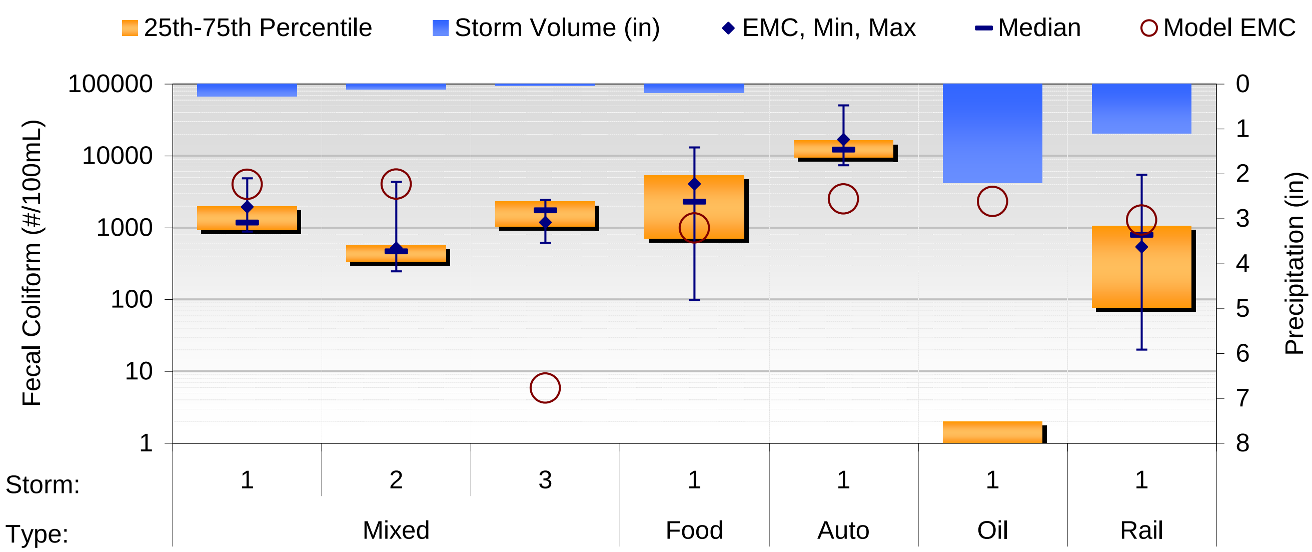


Figure 40. Industrial land use monitoring sites summary for fecal coliform (#/100mL).

Agricultural Land Use Calibration

Figure 41 and Figure 42 are a location/HRU map and a land use distribution chart, respectively, for site LU14, Agricultural-Mixed.

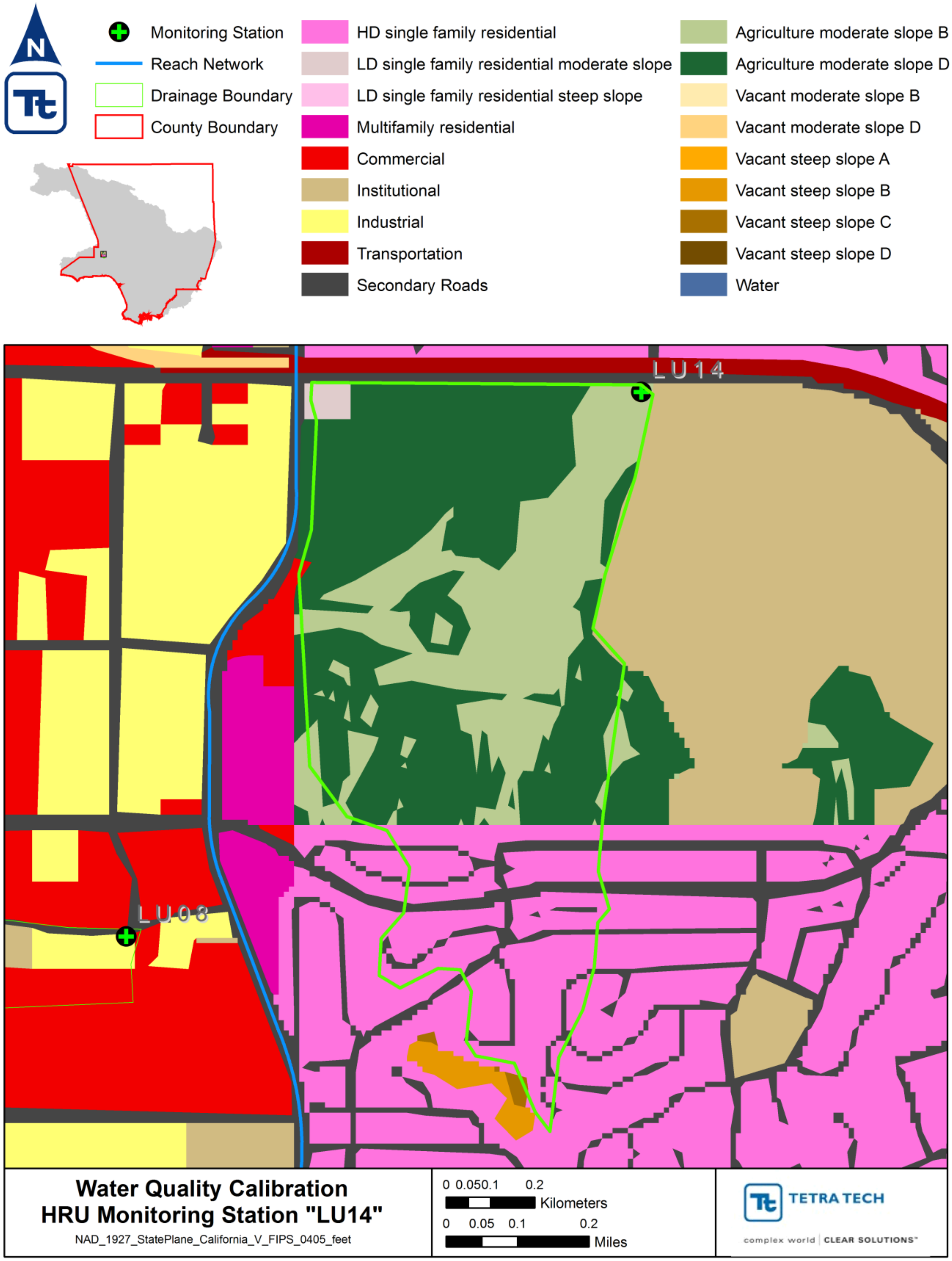


Figure 41. Location and HRU map of site LU14, Agricultural-Mixed.

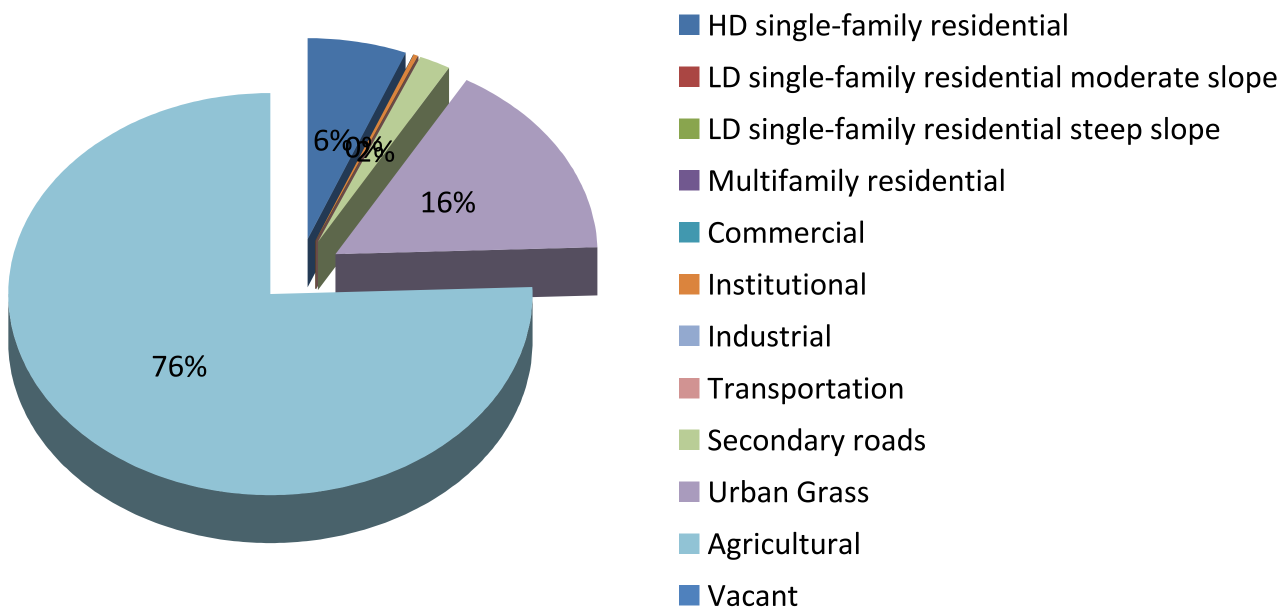


Figure 42. Land use distribution upstream of site LU14, Agricultural-Mixed.

Land use site LU14 Agricultural-Mixed drains an area that is mostly agricultural. It is in the Los Angeles River watershed.

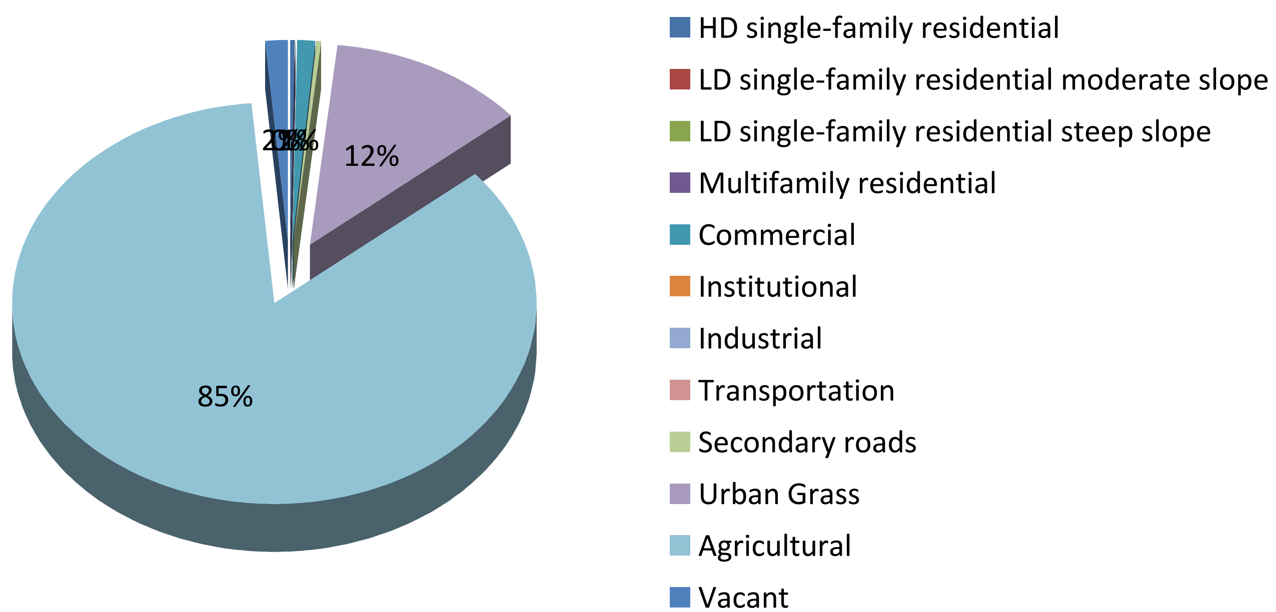


Figure 43. Land use distribution upstream of site LU15, Agricultural-Nursery.

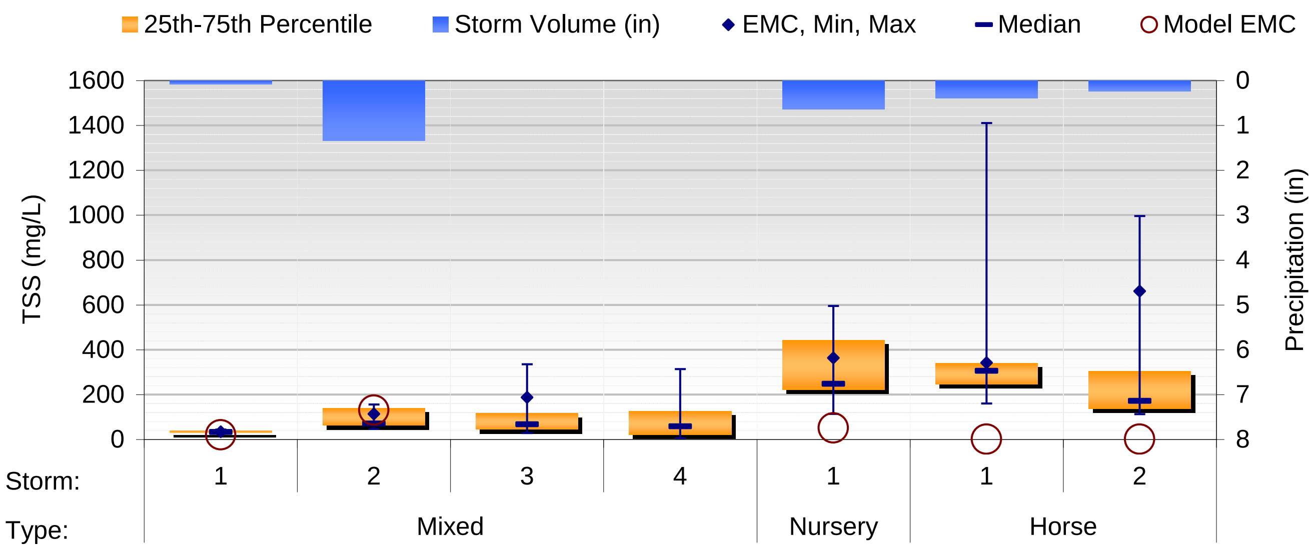


Figure 44. Agricultural land use monitoring sites summary for TSS (mg/L).

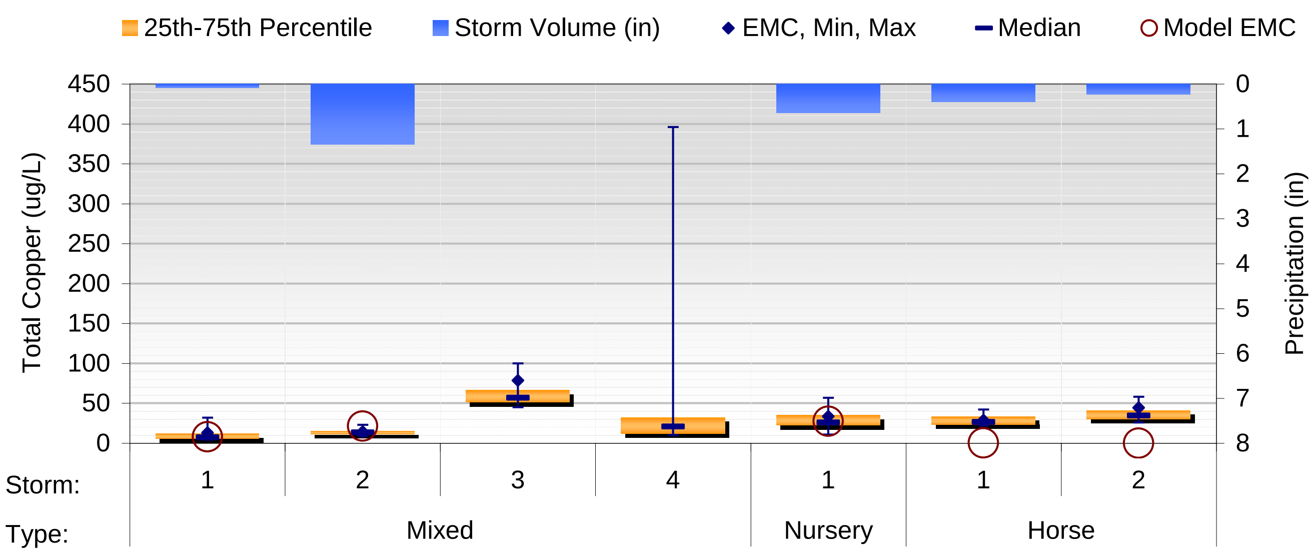


Figure 45. Agricultural land use monitoring sites summary for total Cu (µg/L).

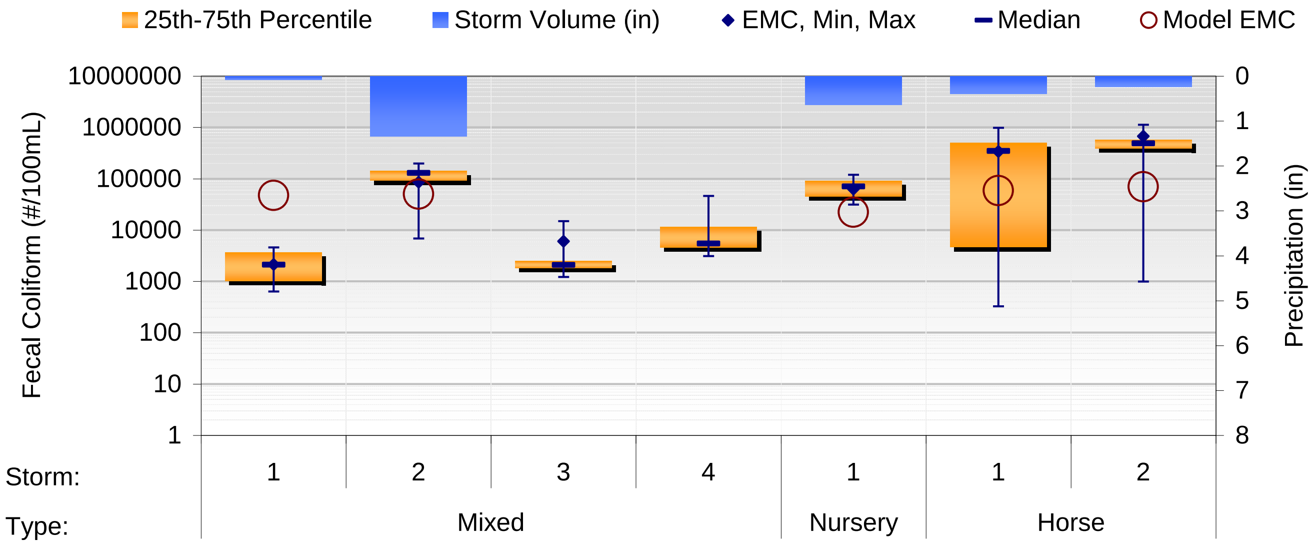
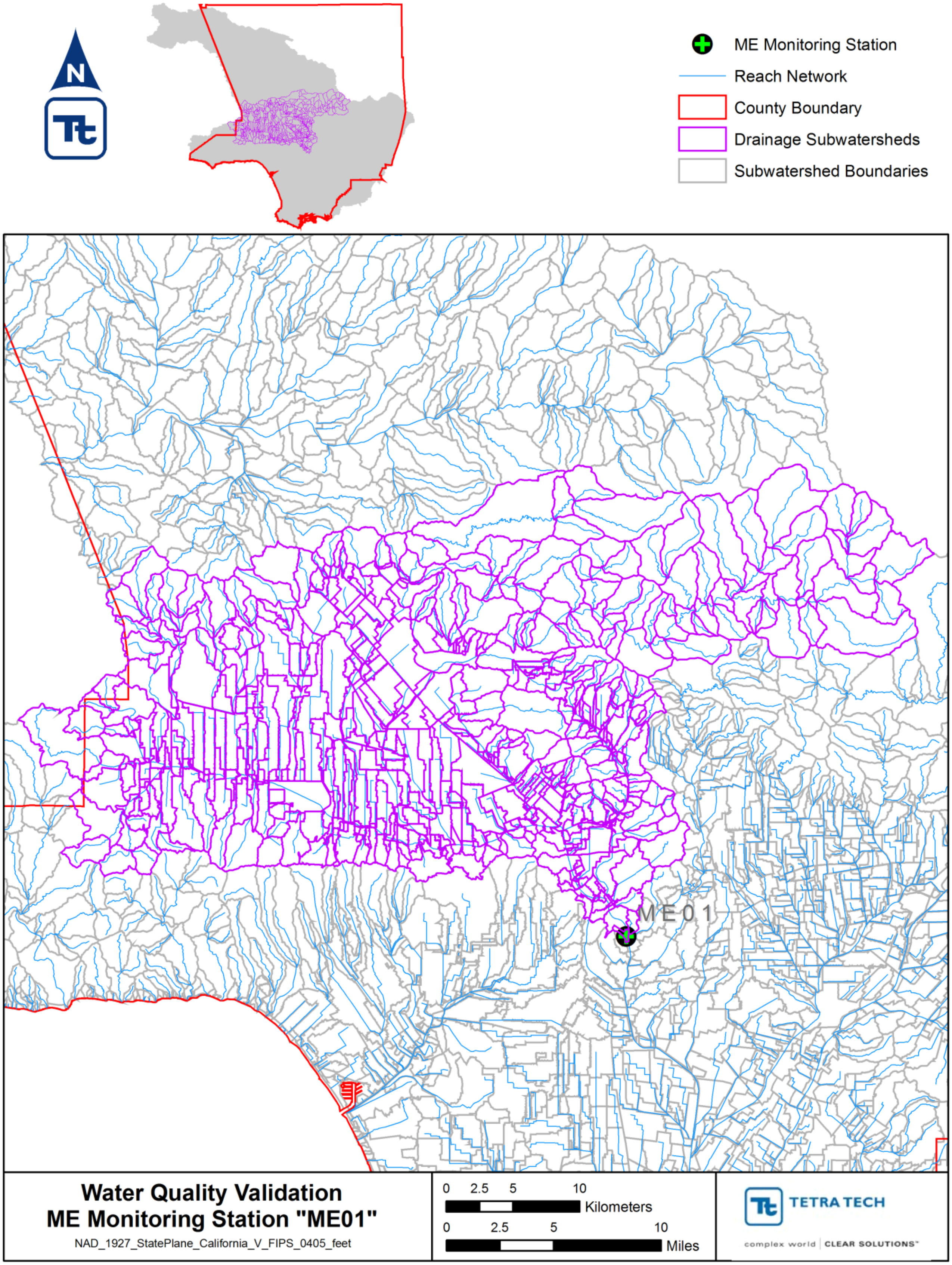


Figure 46. Agricultural land use monitoring sites summary for fecal coliform (#/100mL).

Water Quality Validation

The validation was performed using the downstream mass emission stations and provides an aggregate test of the model performance using a static set of calibrated parameters. That provides a test of the model behavior using a separate data set, but it does not require splitting the available data temporally and provides testing of a wide range of storm sizes and hydrologic conditions. The downstream gages selected for model testing include drainage areas that are composed of a mix of HRUs, providing a good test of the aggregate response of the subwatersheds and the predictive capability of the HRU simulation. Because the watershed-scale model is being run on an hourly timestep, the validation results are also presented on an hourly timestep. The following sections provide a summary of the validation results for the selected stations for each pollutant. For each validation point, the HRUs that compose the drainage area are provided for reference as well.



Water Quality Validation
ME Monitoring Station "ME01"
NAD_1927_StatePlane_California_V_FIPS_0405_feet

Figure 47. Location and drainage areas of mass emission site ME01.

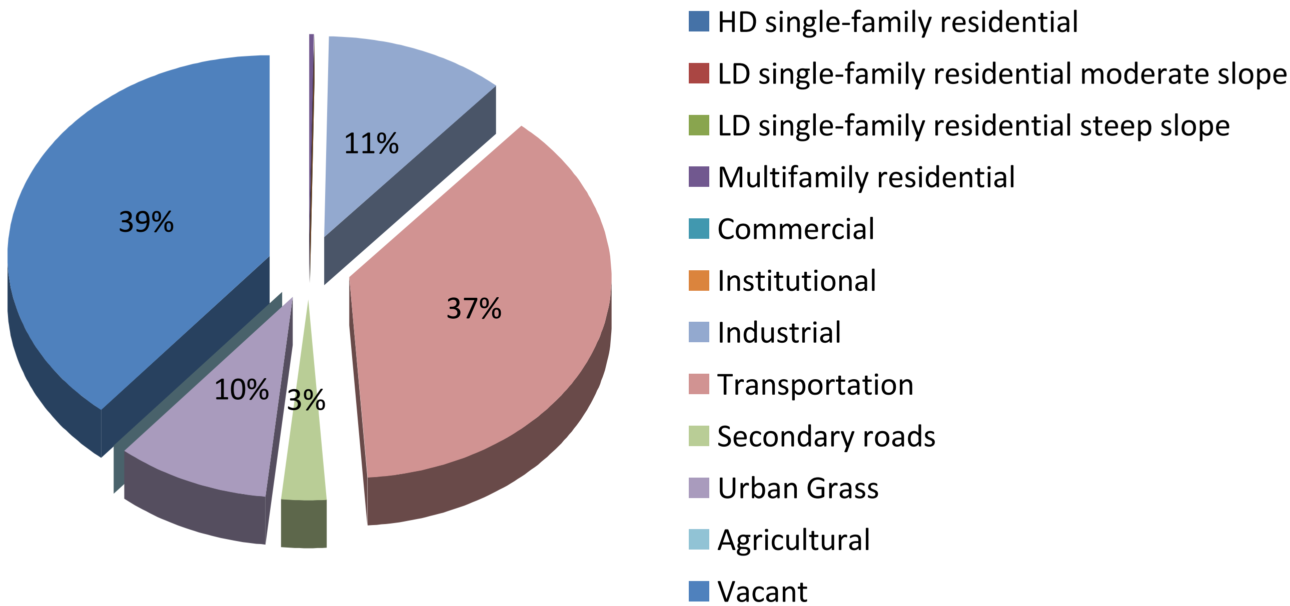


Figure 48. Land use distribution upstream of mass emission site ME01.

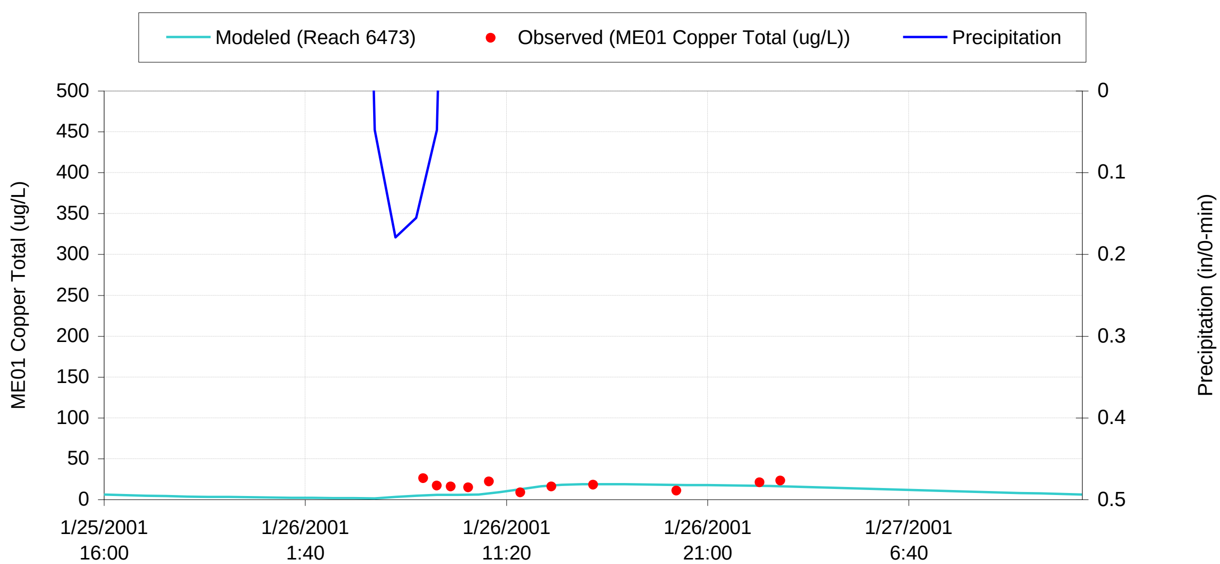


Figure 49. Modeled vs. observed ME01 total Cu (µg/L) at subbasin 6473.

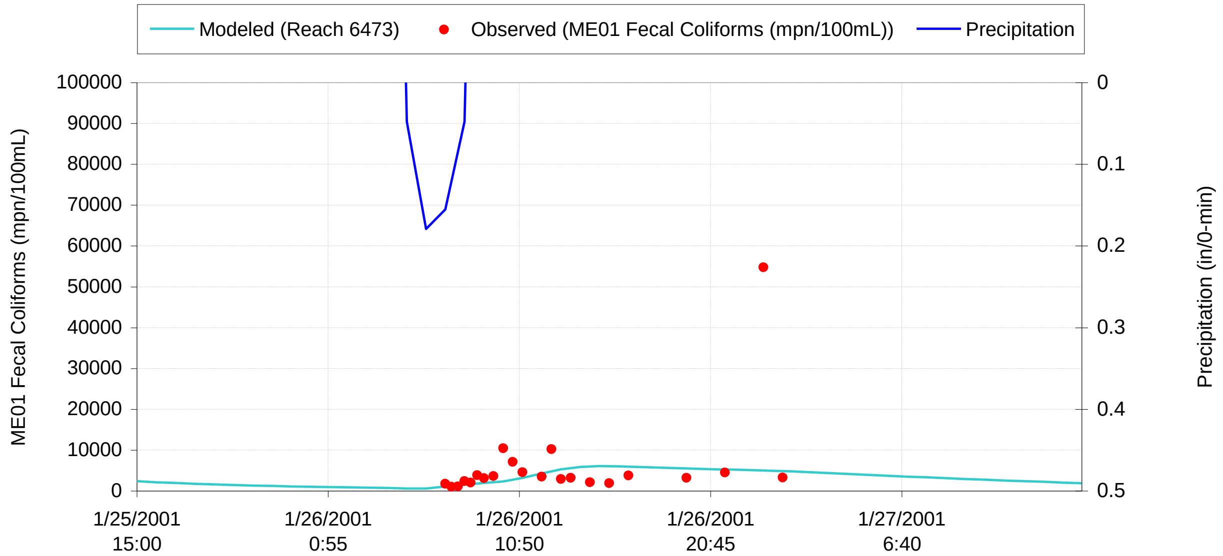


Figure 50. Modeled vs. observed ME01 fecal coliform (mpn/100mL) at subbasin 6473.

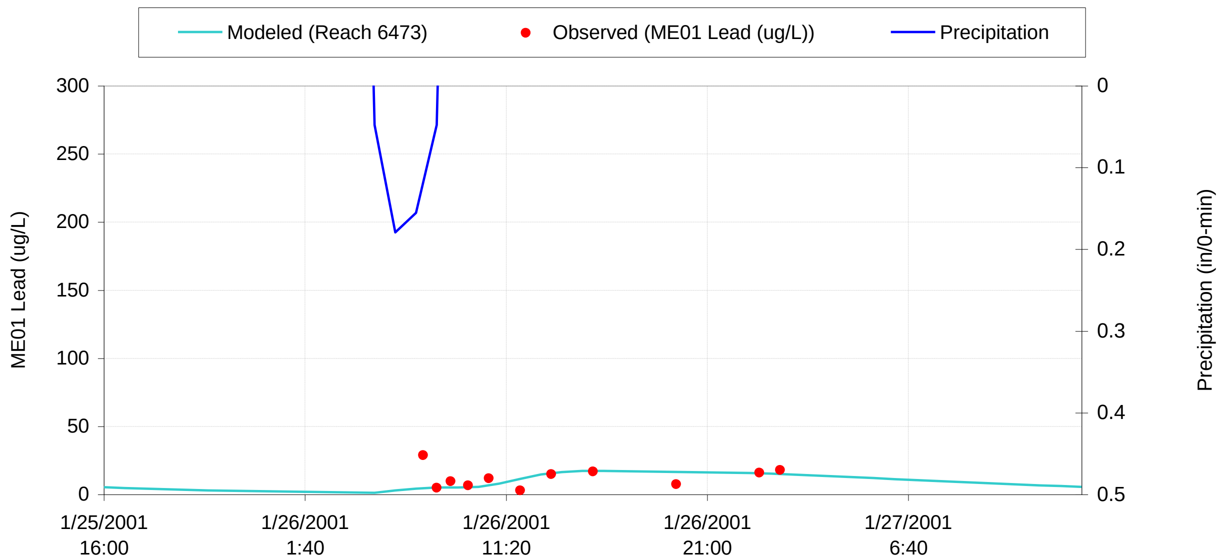


Figure 51. Modeled vs. observed ME01 Pb (µg/L) at subbasin 6473.

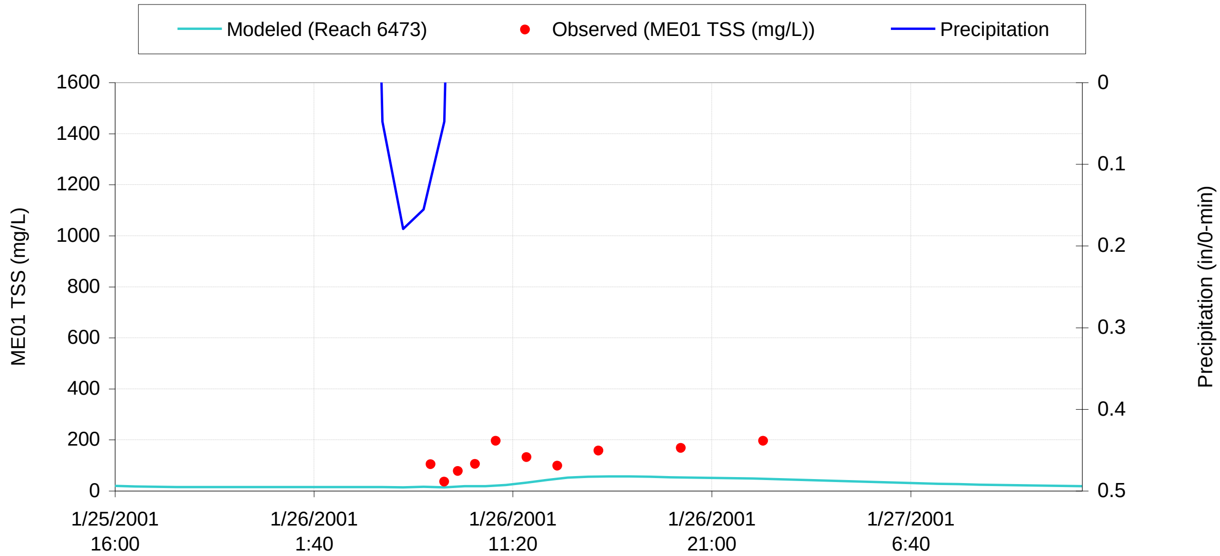


Figure 52. Modeled vs. observed ME01 TSS (mg/L) at subbasin 6473.

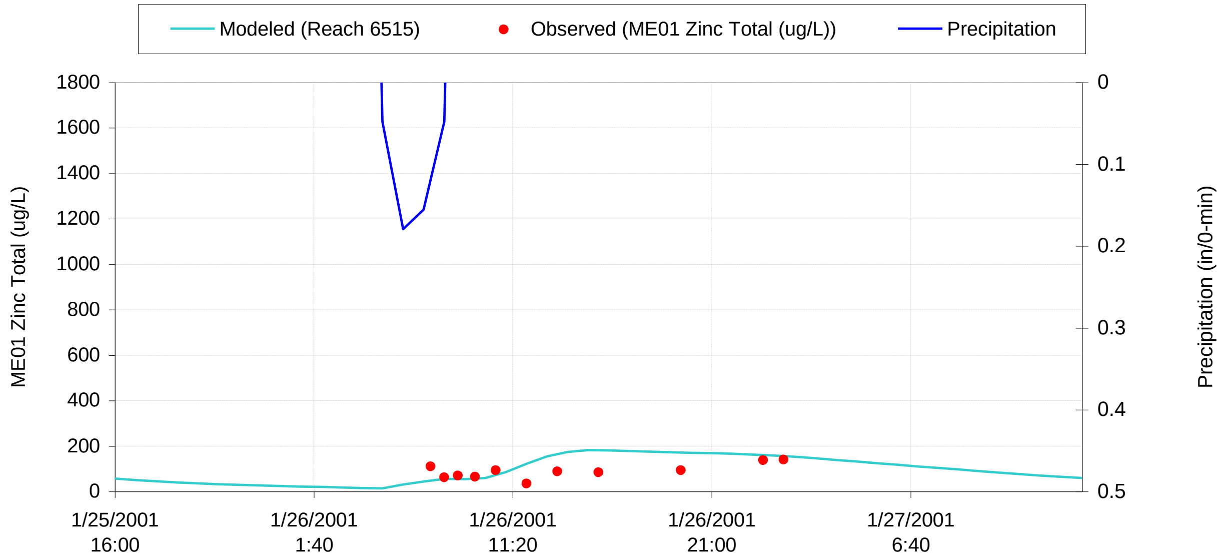


Figure 53. Modeled vs. observed ME01 Zn total (µg/L) at subbasin 6473.

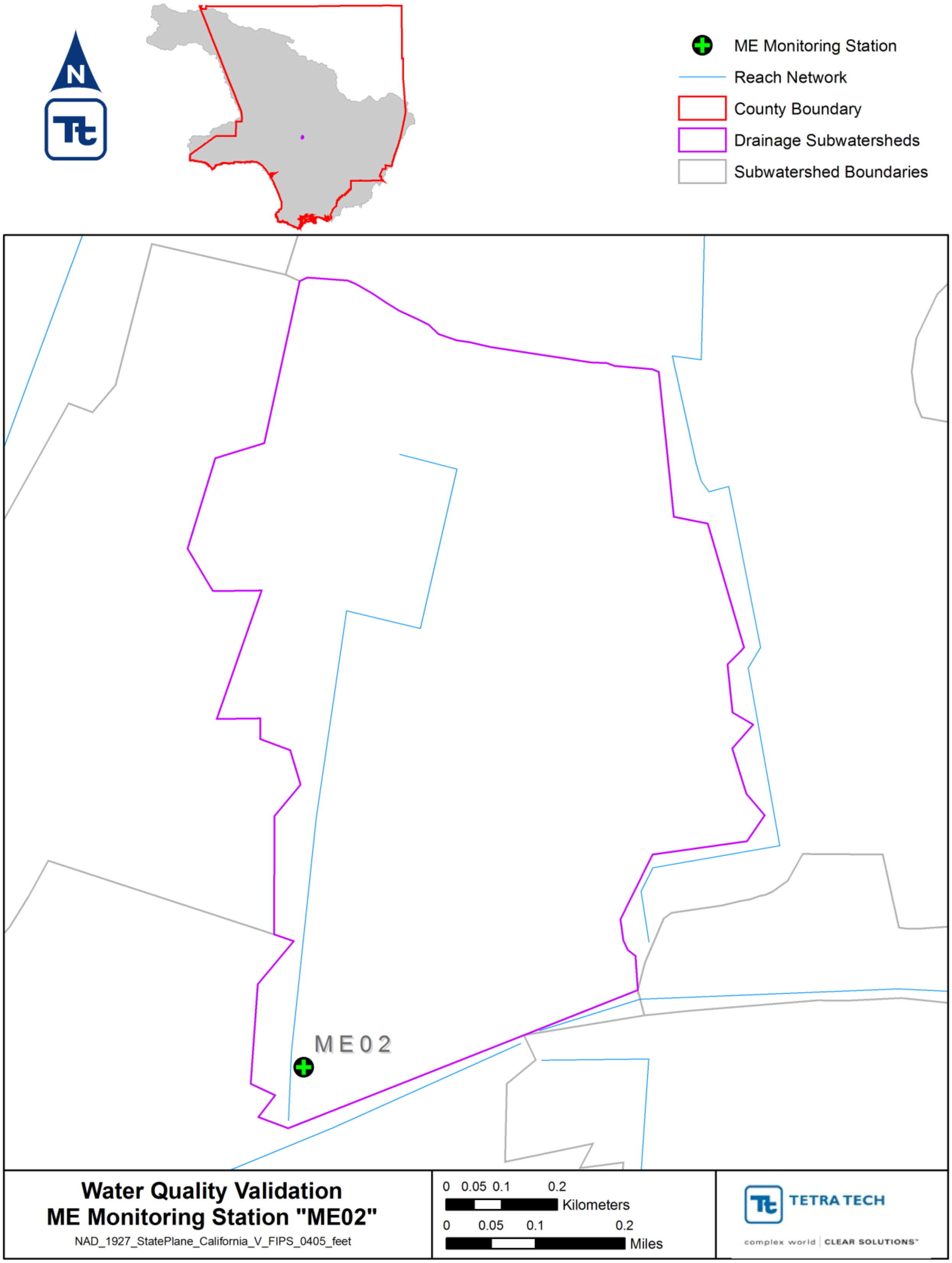


Figure 54. Location and drainage areas of mass emission site ME02.

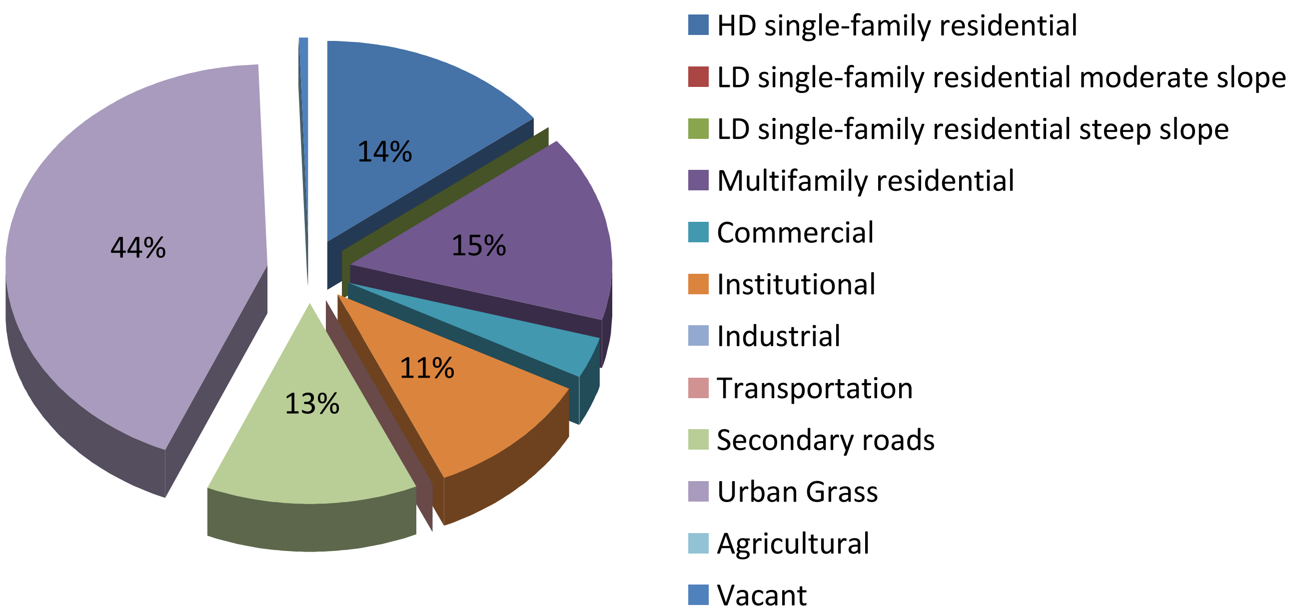


Figure 55. Land use distribution upstream of mass emission site ME02.

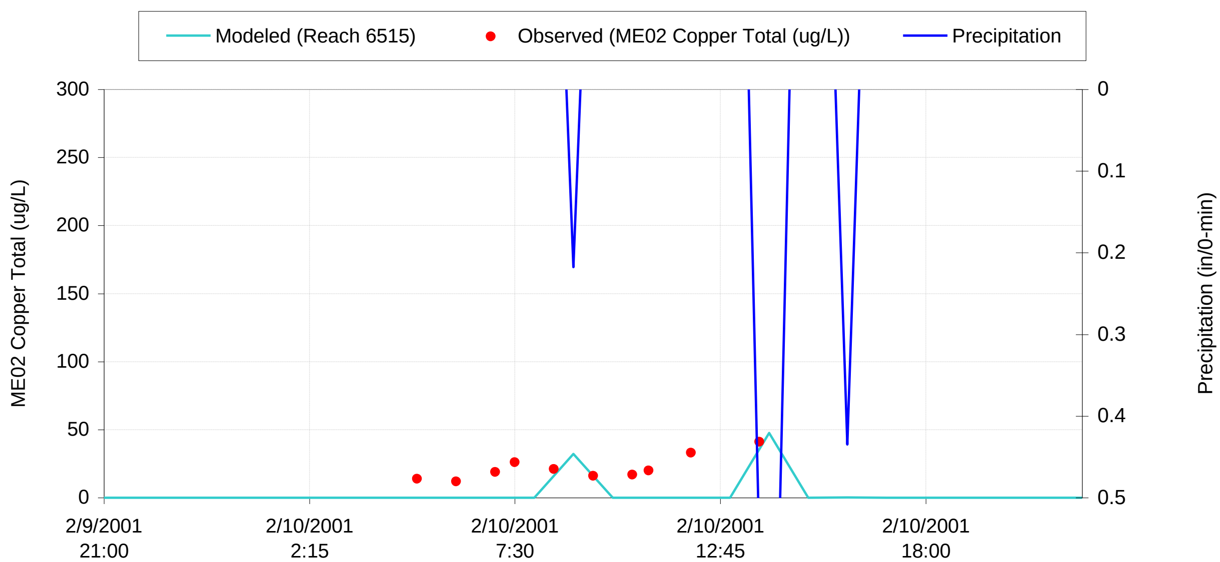


Figure 56. Modeled vs. observed ME02 Cu total (µg/L) at subbasin 6515.

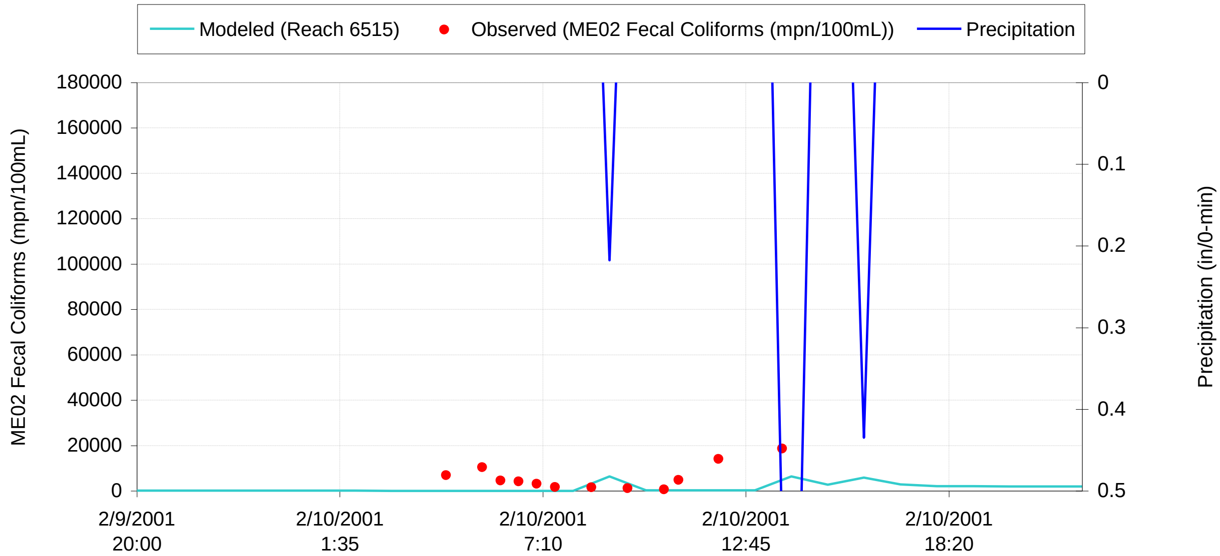


Figure 57. Modeled vs. observed ME02 fecal coliform (mpn/100mL) at subbasin 6515.

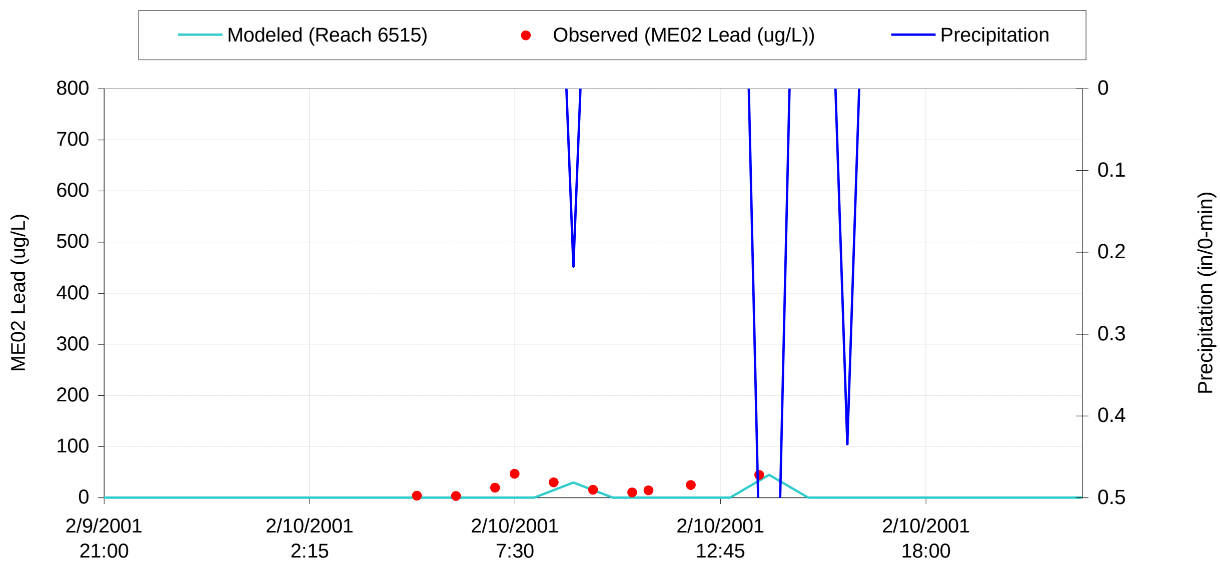


Figure 58. Modeled vs. observed ME02 Pb (µg/L) at subbasin 6515.

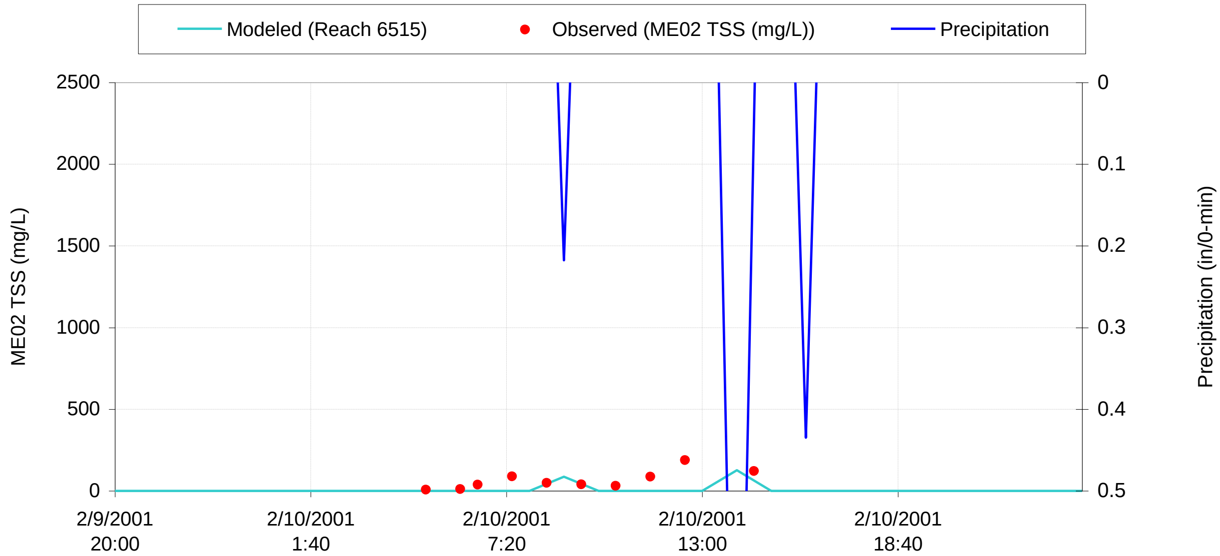


Figure 59. Modeled vs. observed ME02 TSS (mg/L) at subbasin 6515.

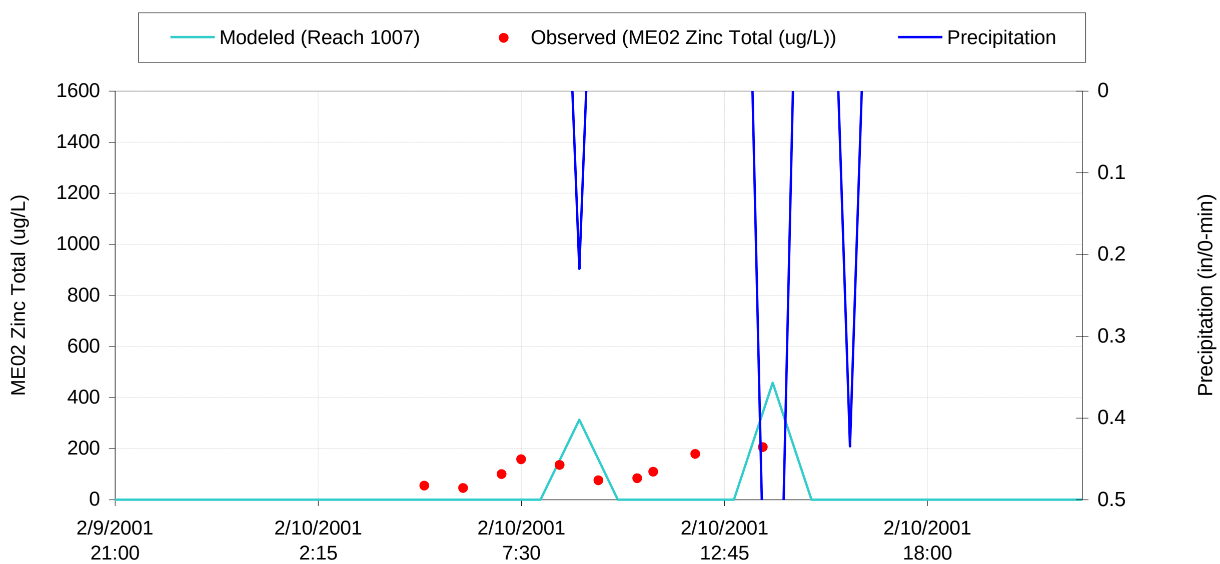


Figure 60. Modeled vs. observed ME02 Zn total (µg/L) at subbasin 6515.

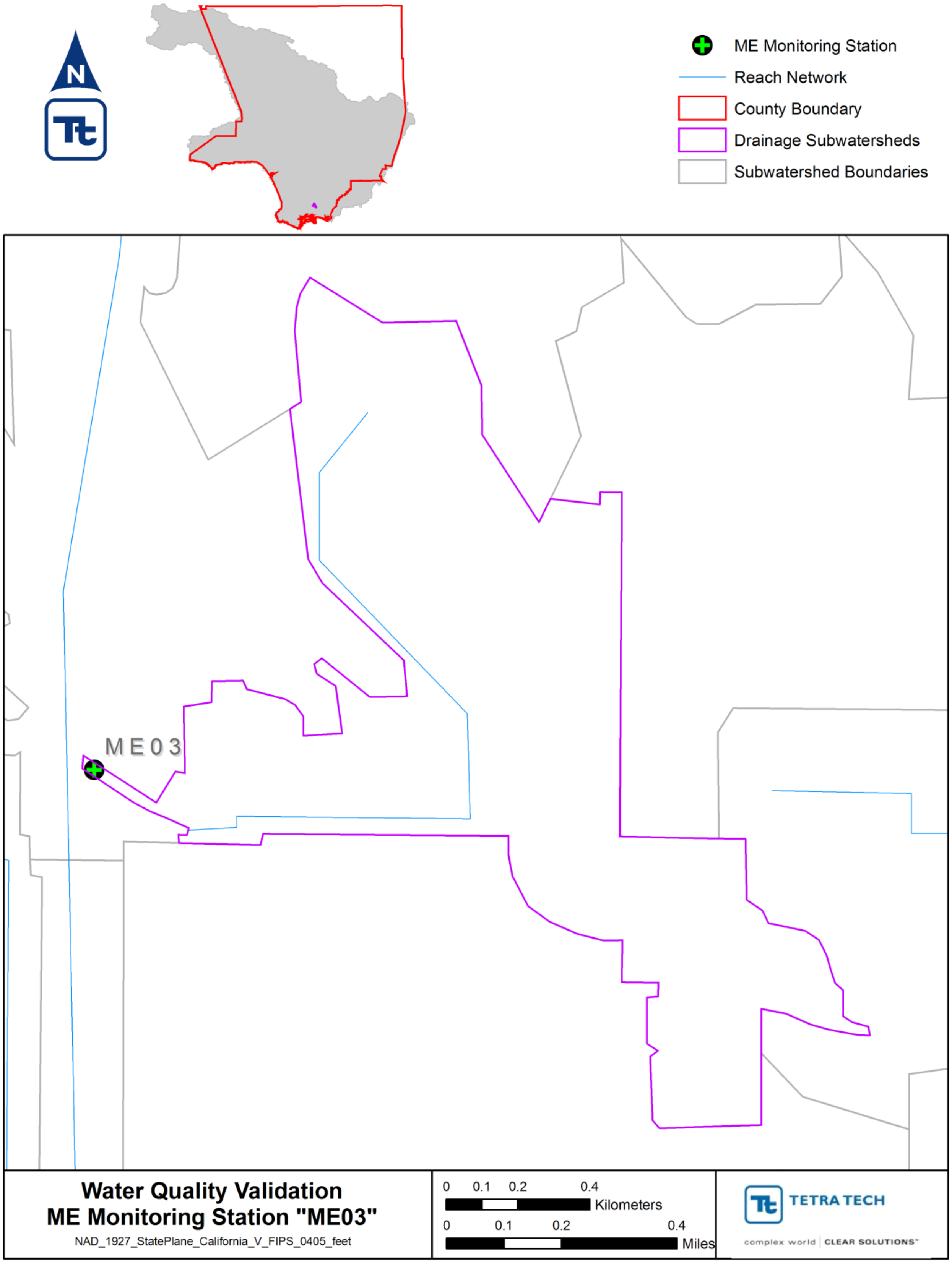


Figure 61. Location and drainage areas of mass emission site ME03.

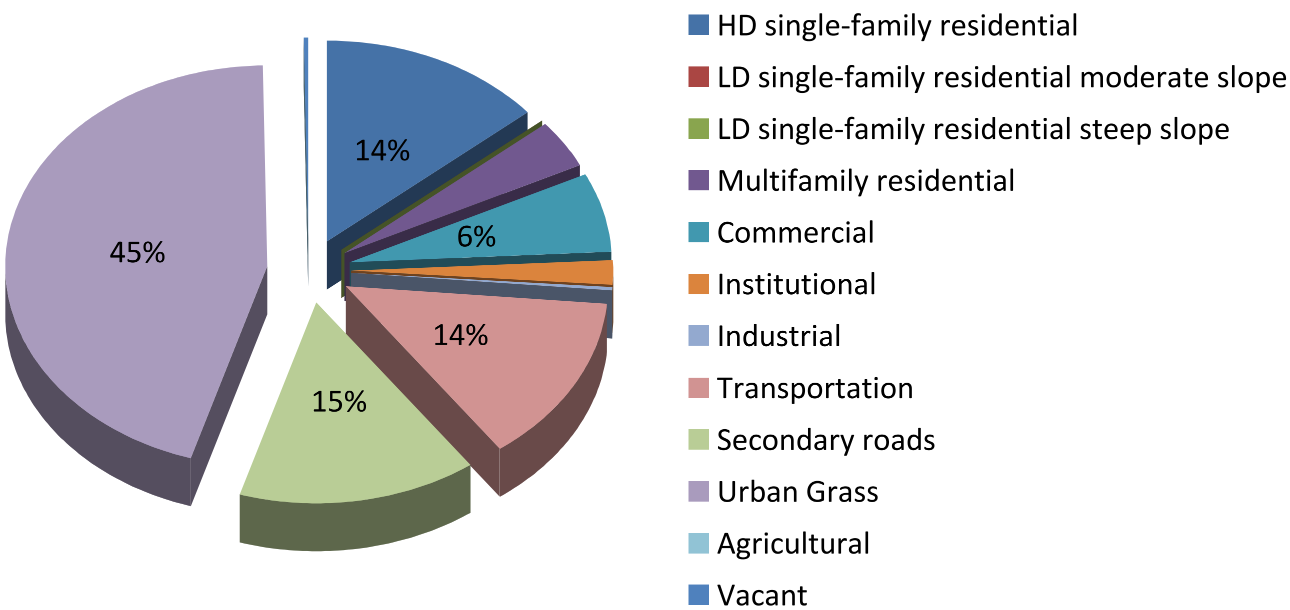


Figure 62. Land use distribution upstream of mass emission site ME03.

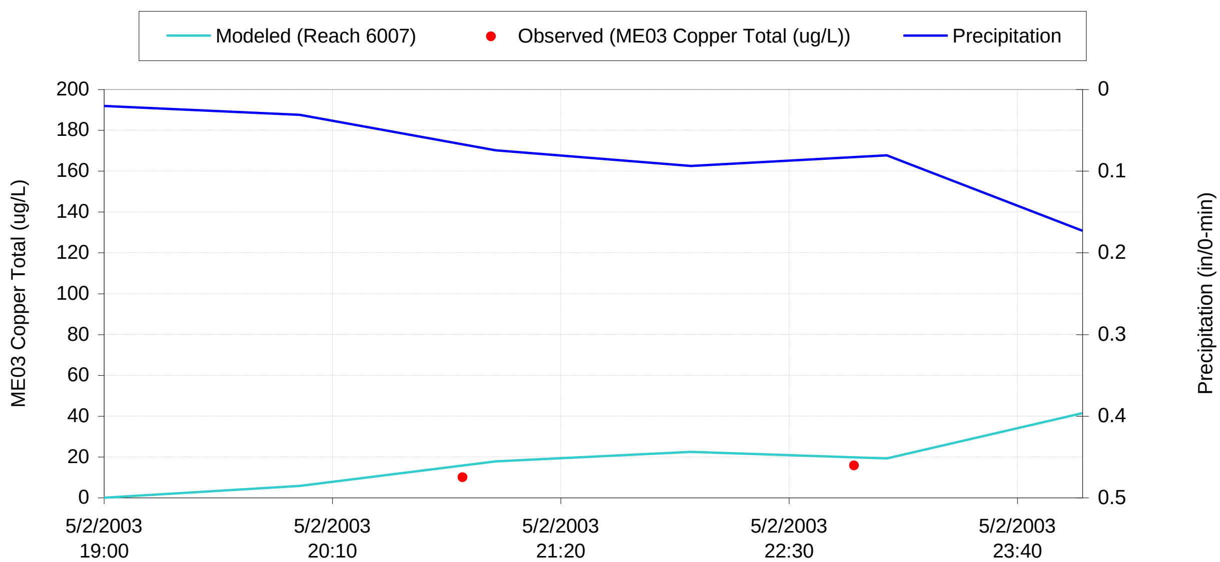


Figure 63. Modeled vs. observed ME03 Cu total (µg/L) at subbasin 6007.

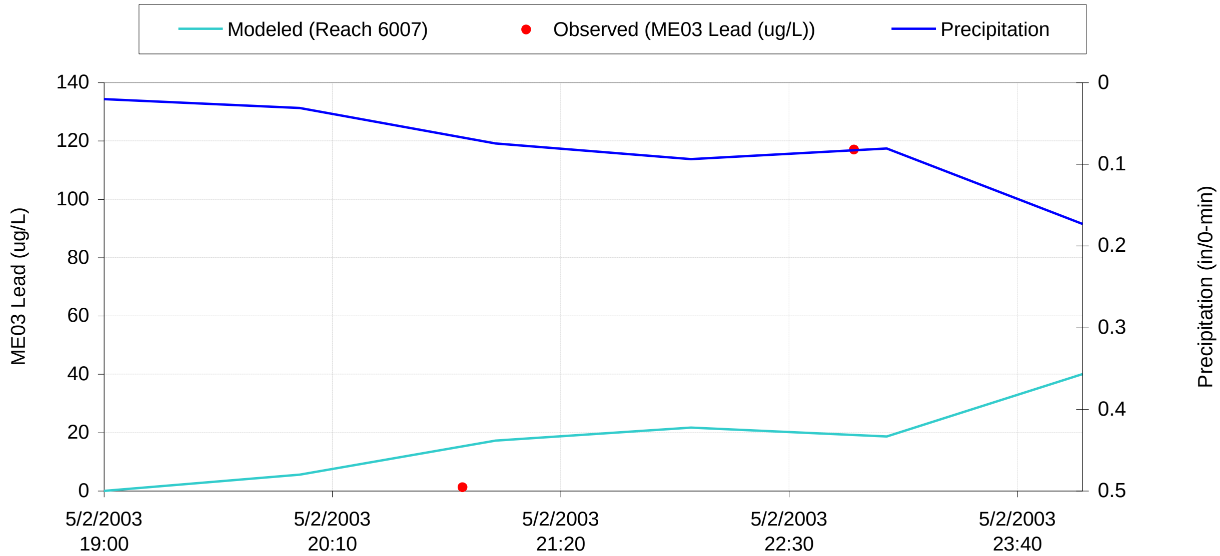


Figure 64. Modeled vs. observed ME03 Pb (µg/L) at subbasin 6007.

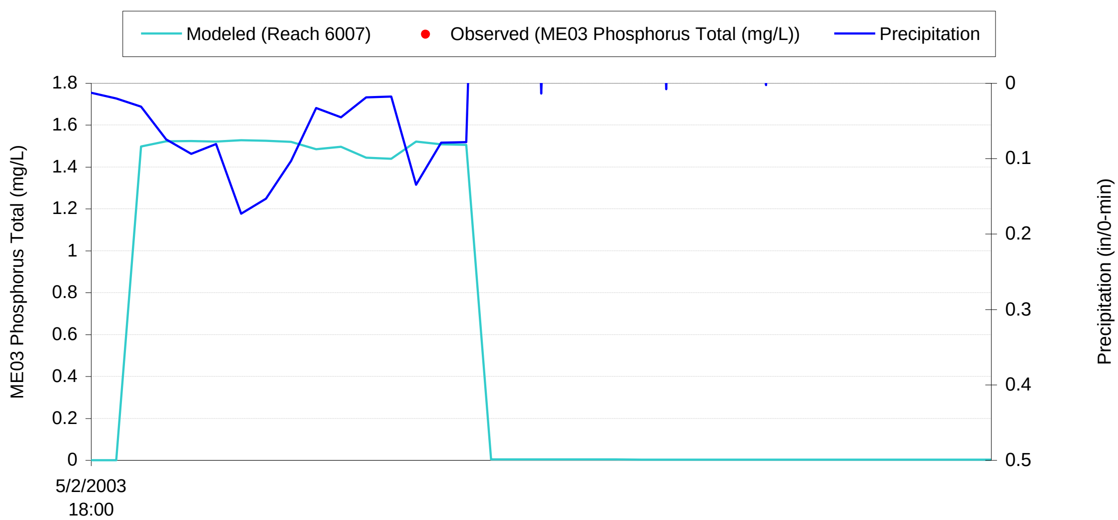


Figure 65. Modeled vs. observed ME03 phosphorus total (mg/L) at subbasin 6007.

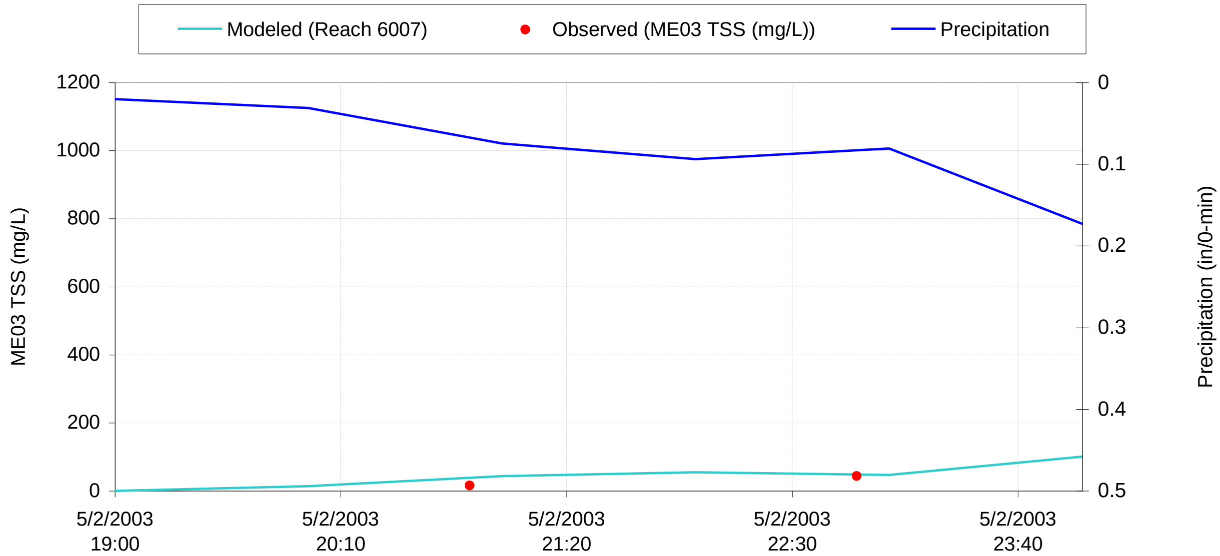


Figure 66. Modeled vs. observed ME03 TSS (mg/L) at subbasin 6007.

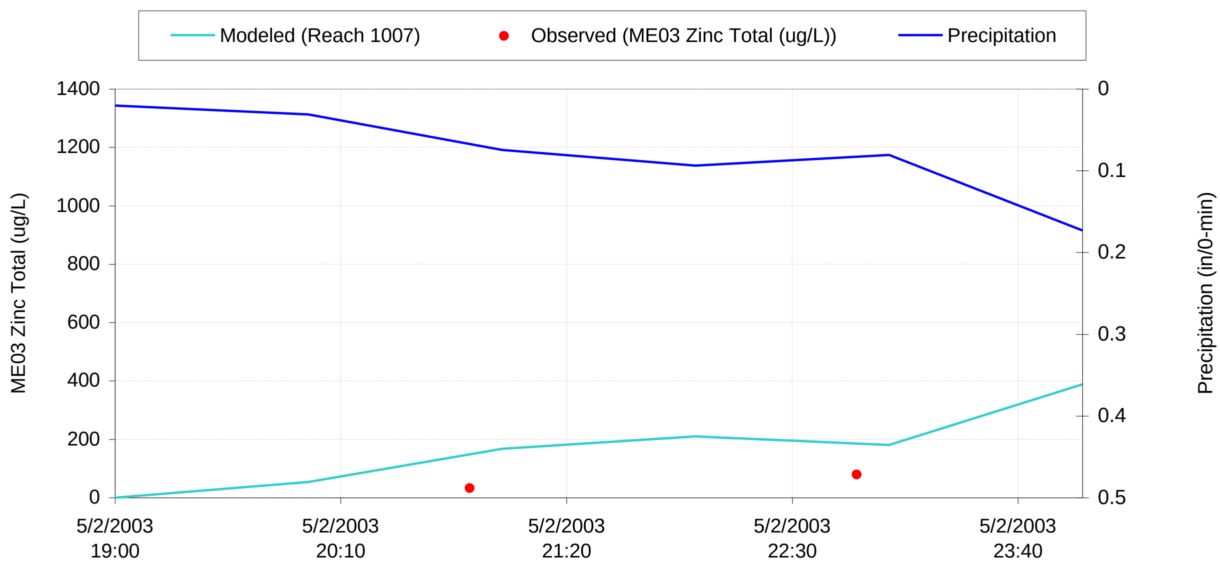


Figure 67. Modeled vs. observed ME03 Zn total (µg/L) at subbasin 6007.

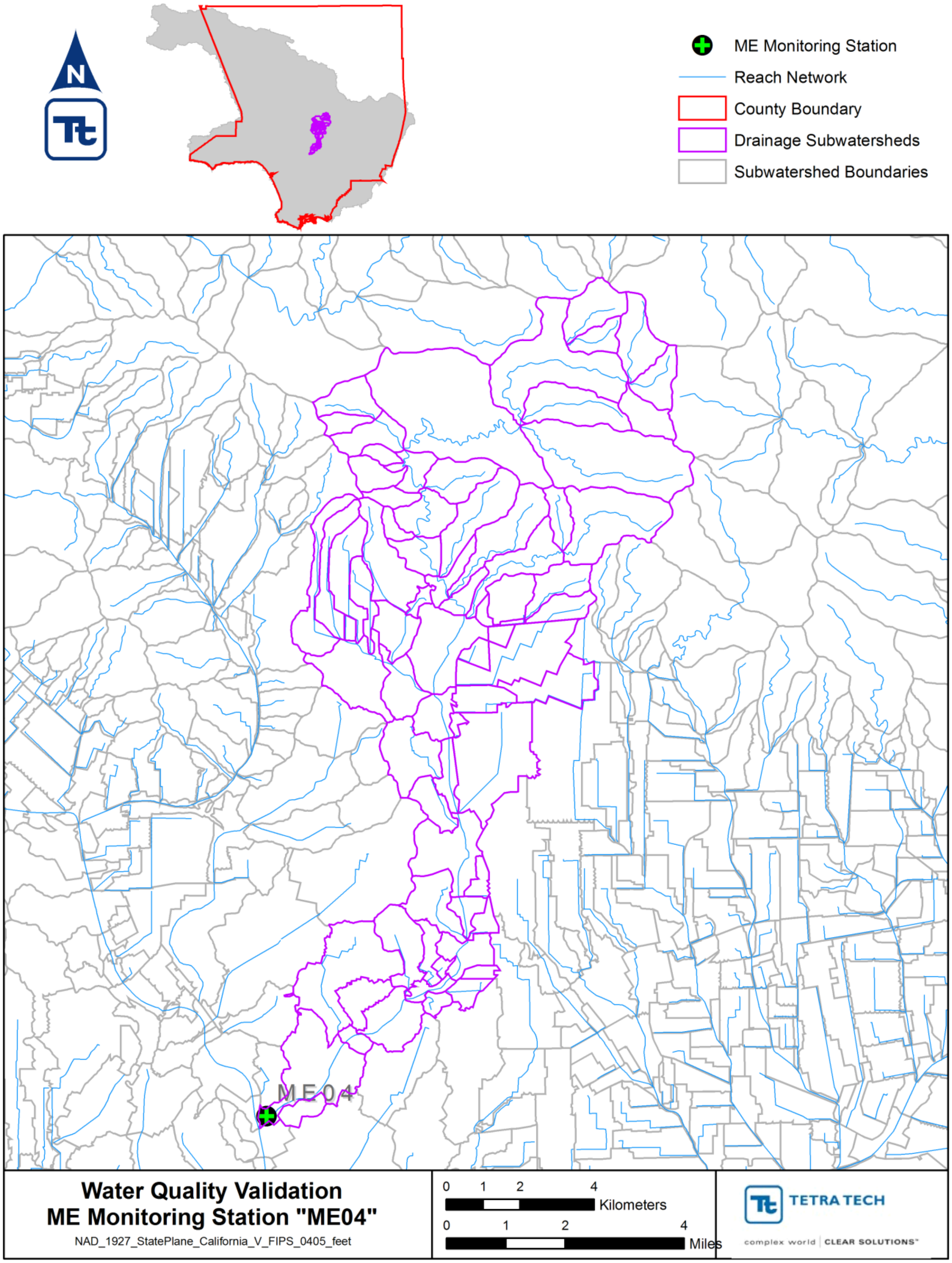


Figure 68. Location and drainage areas of mass emission site ME04.

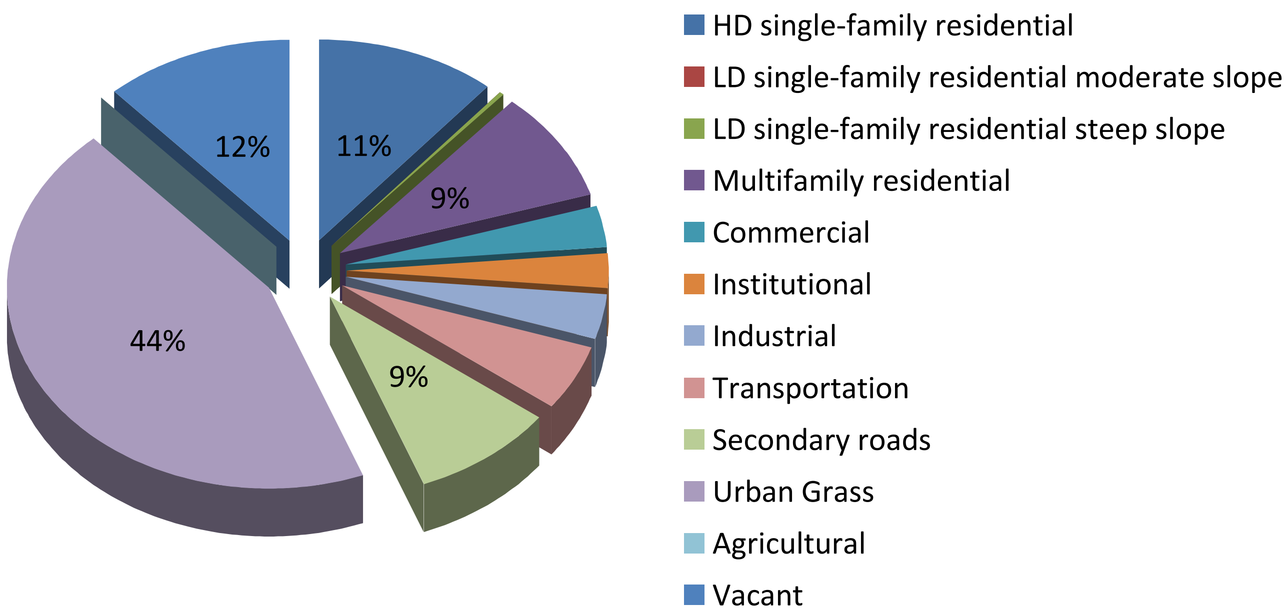


Figure 69. Land use distribution upstream of mass emission site ME04.

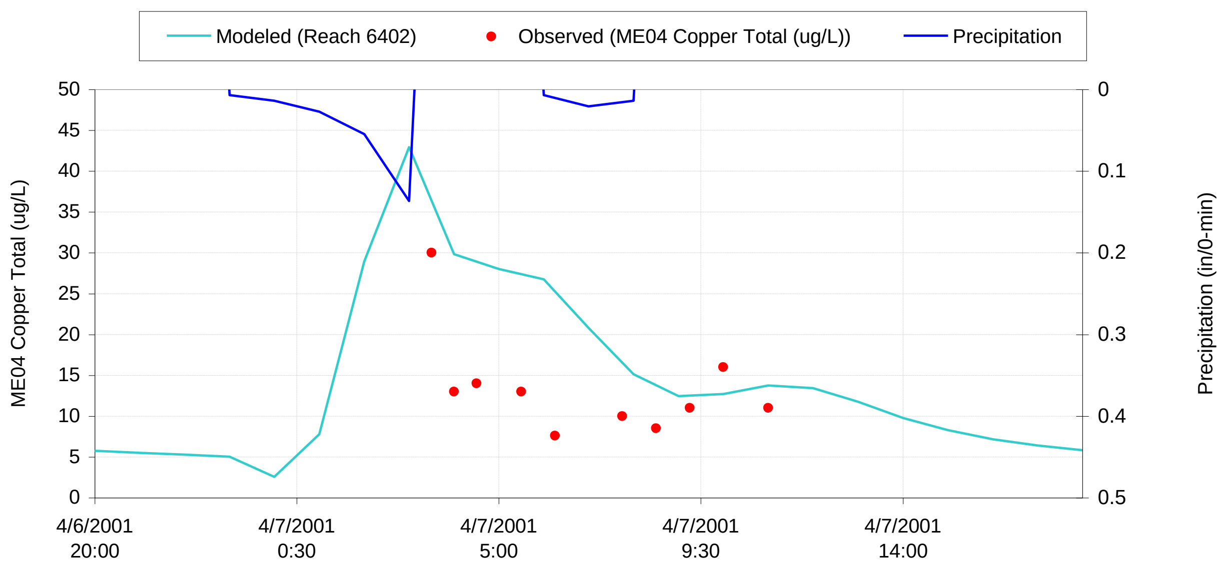


Figure 70. Modeled vs. observed ME04 Cu total (µg/L) at subbasin 6402.

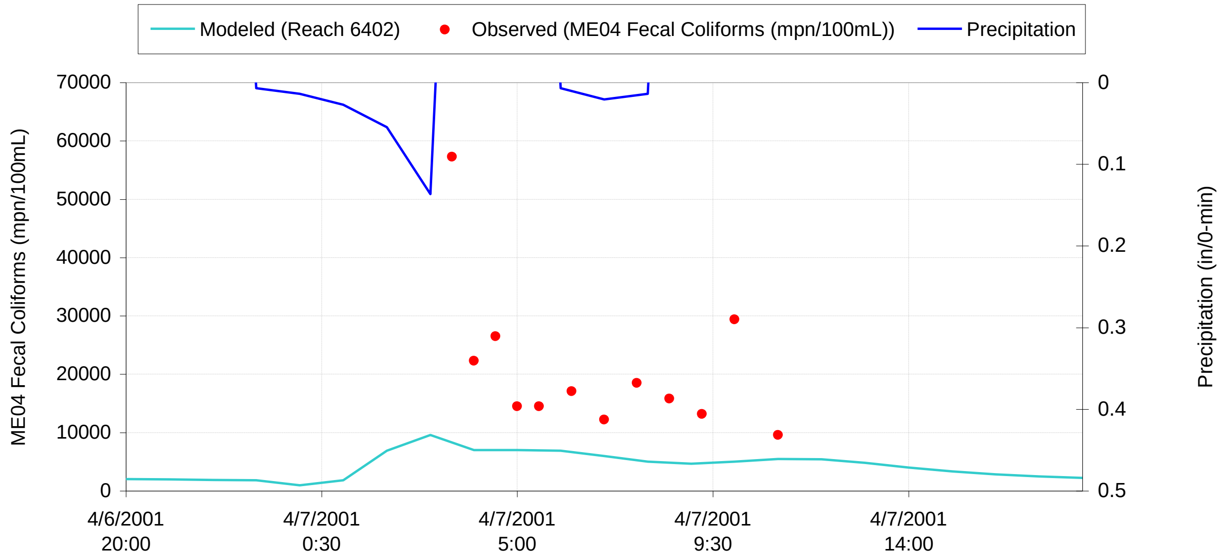


Figure 71. Modeled vs. observed ME04 fecal coliform (mpn/100mL) at subbasin 6402.

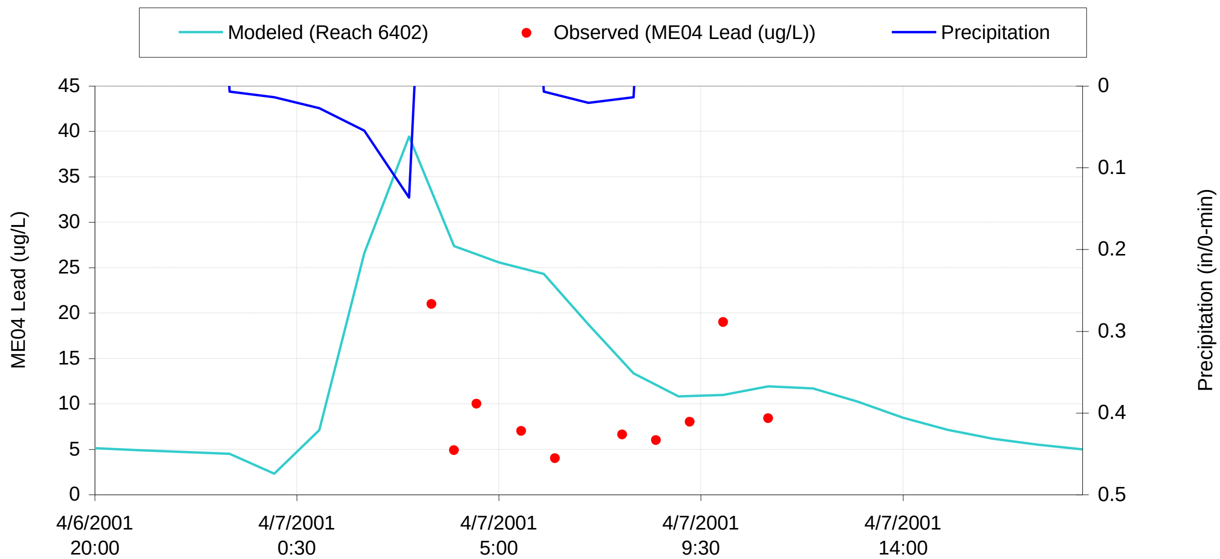


Figure 72. Modeled vs. observed ME04 Pb (µg/L) at subbasin 6402.

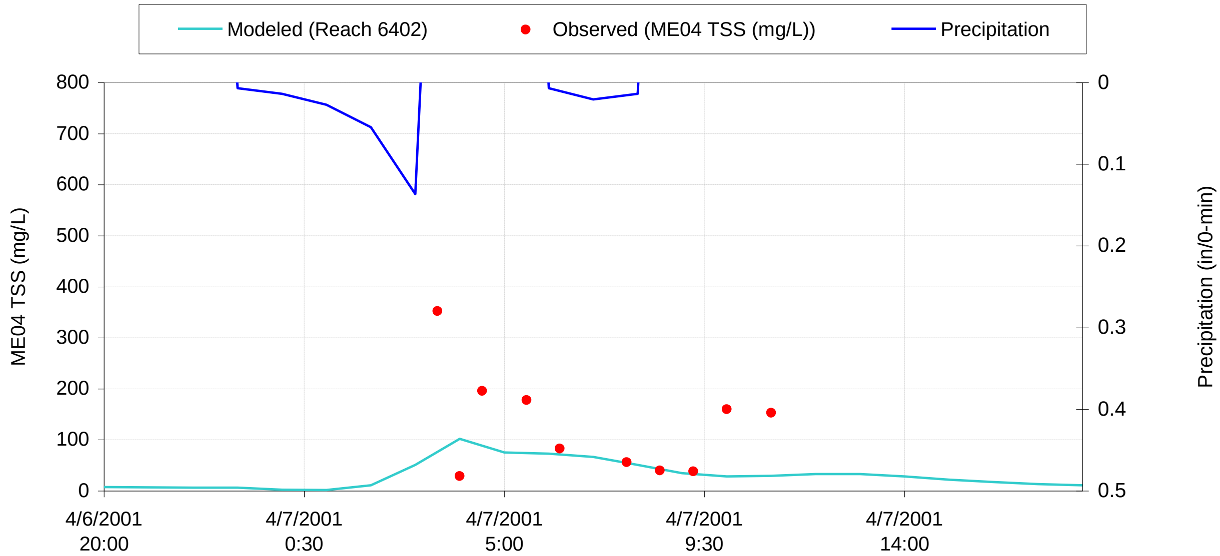


Figure 73. Modeled vs. observed ME04 TSS (mg/L) at subbasin 6402.

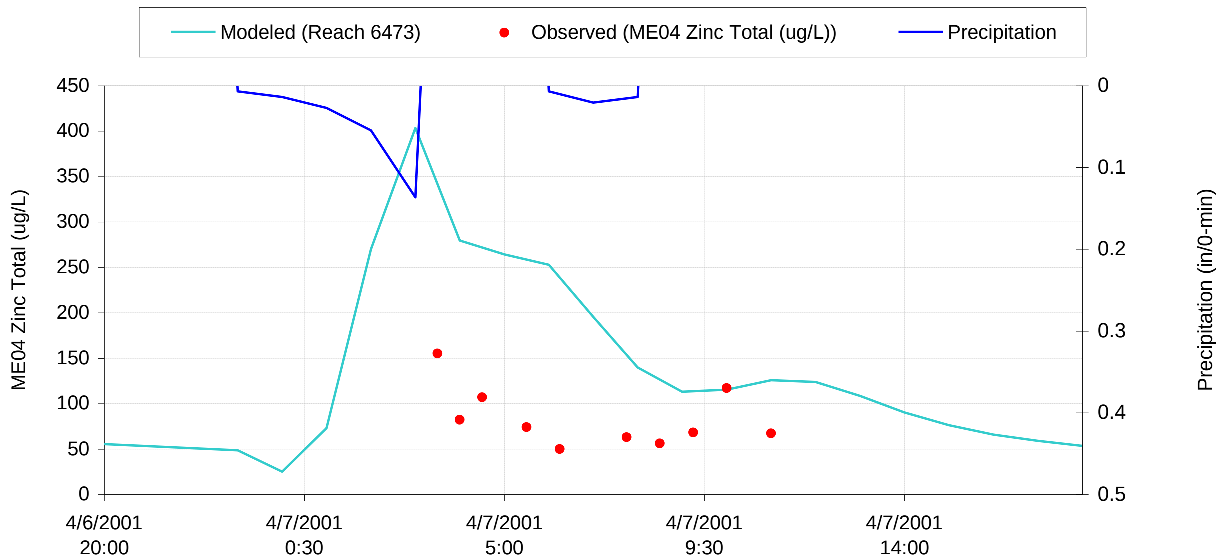


Figure 74. Modeled vs. observed ME04 Zn total (µg/L) at subbasin 6402.

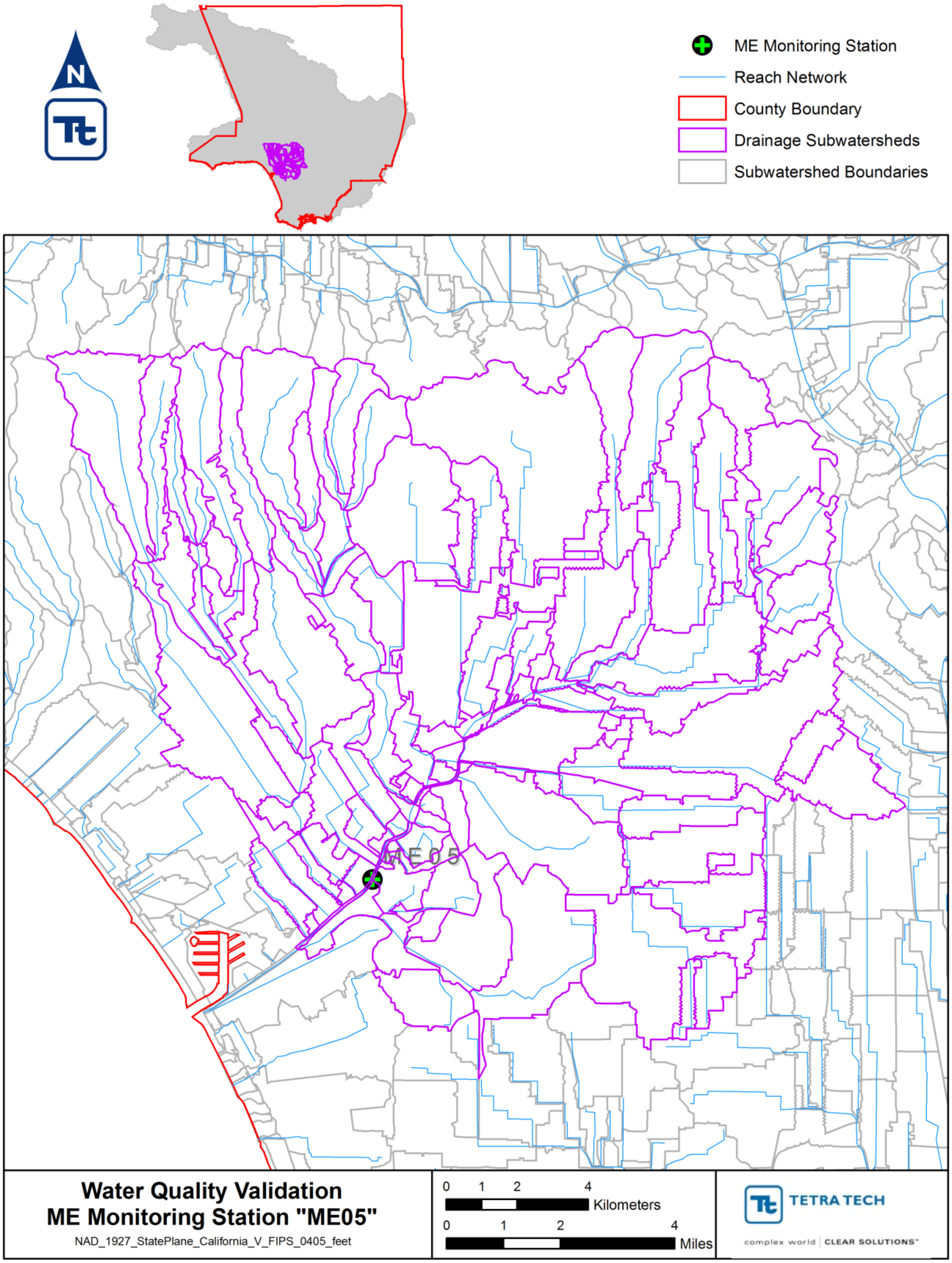


Figure 75. Location and drainage areas of mass emission site ME05.

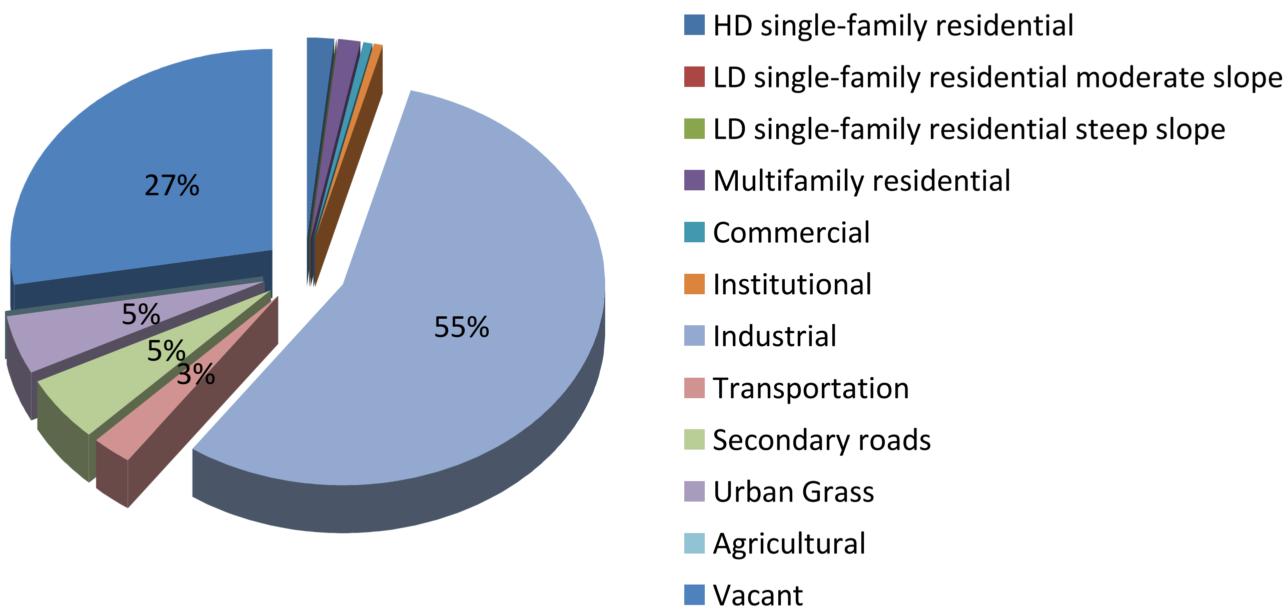


Figure 76. Land use distribution upstream of mass emission site ME05.

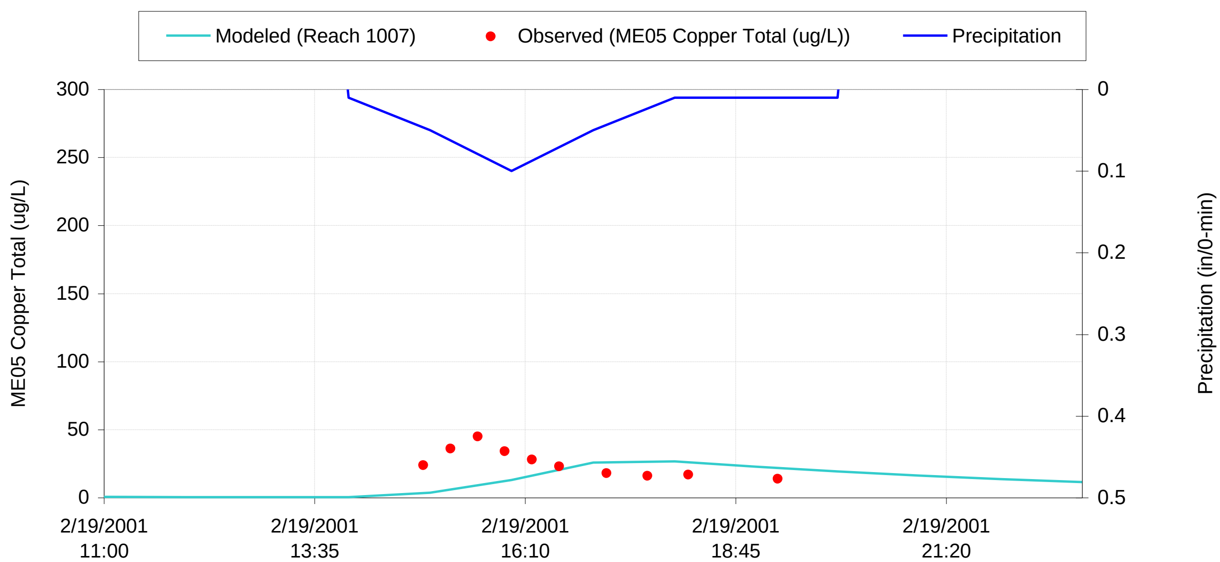


Figure 77. Modeled vs. observed ME05 Cu total (µg/L) at subbasin 1007.

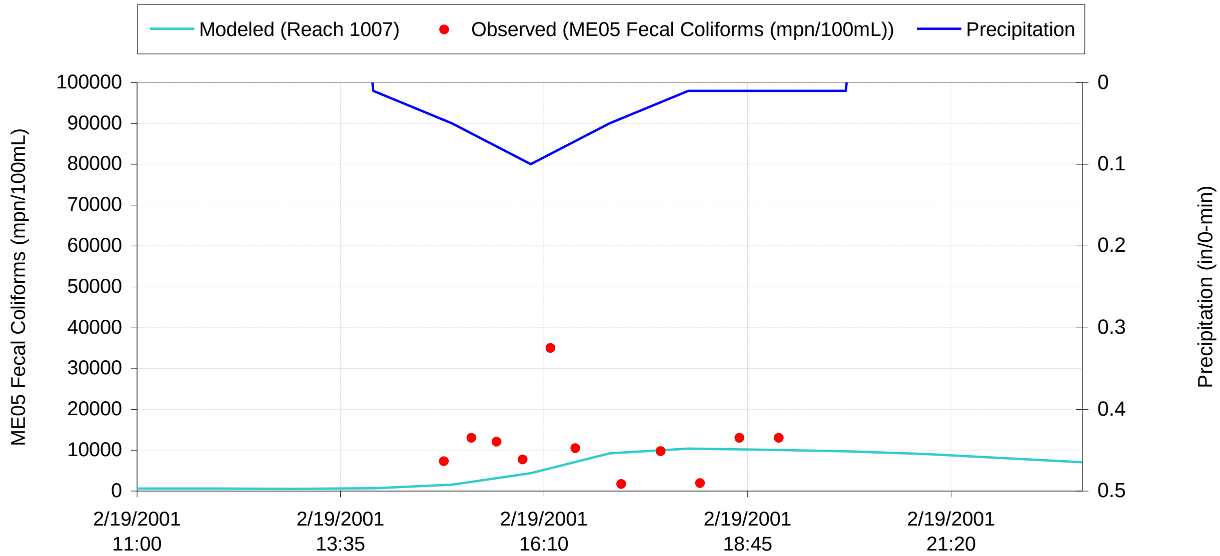


Figure 78. Modeled vs. observed ME05 fecal coliform (mpn/100mL) at subbasin 1007.

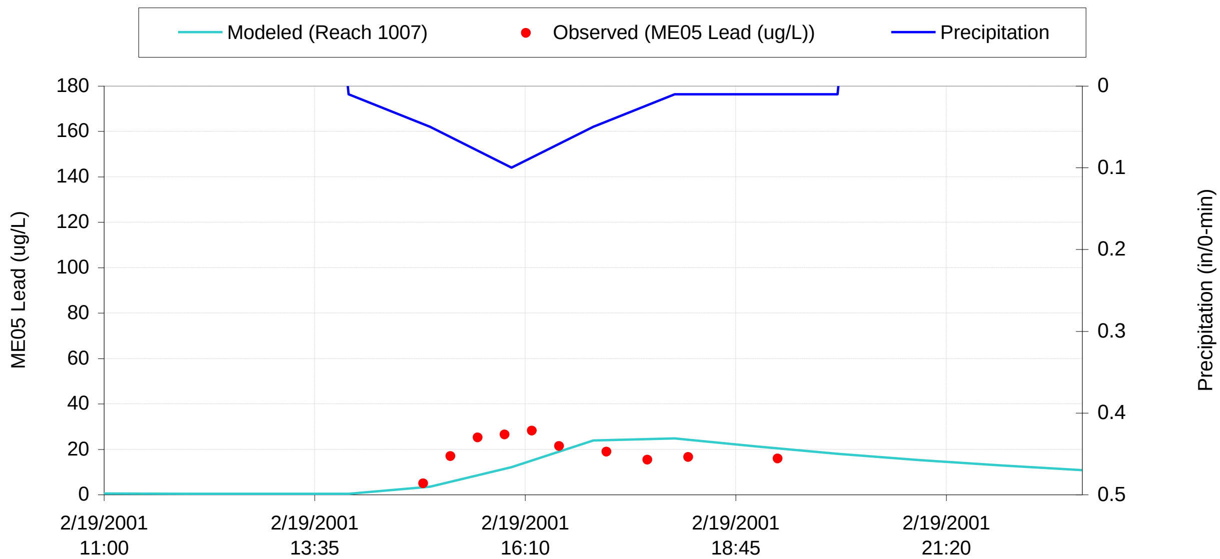


Figure 79. Modeled vs. observed ME05 Pb (µg/L) at subbasin 1007.

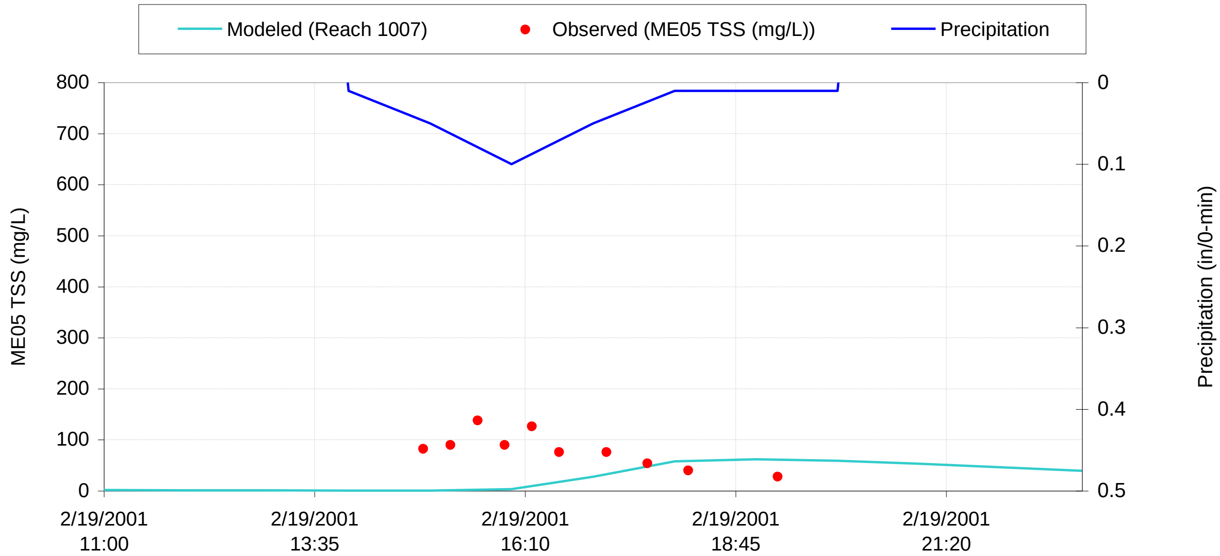


Figure 80. Modeled vs. observed ME05 TSS (mg/L) at subbasin 1007.

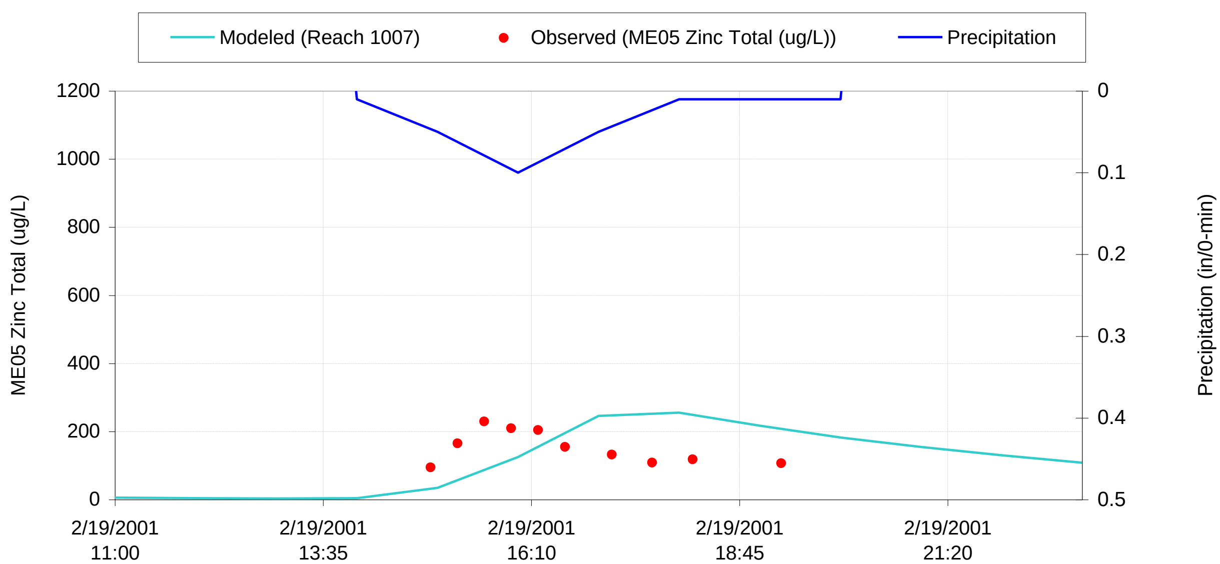


Figure 81. Modeled vs. observed ME05 Zn total (µg/L) at subbasin 1007.

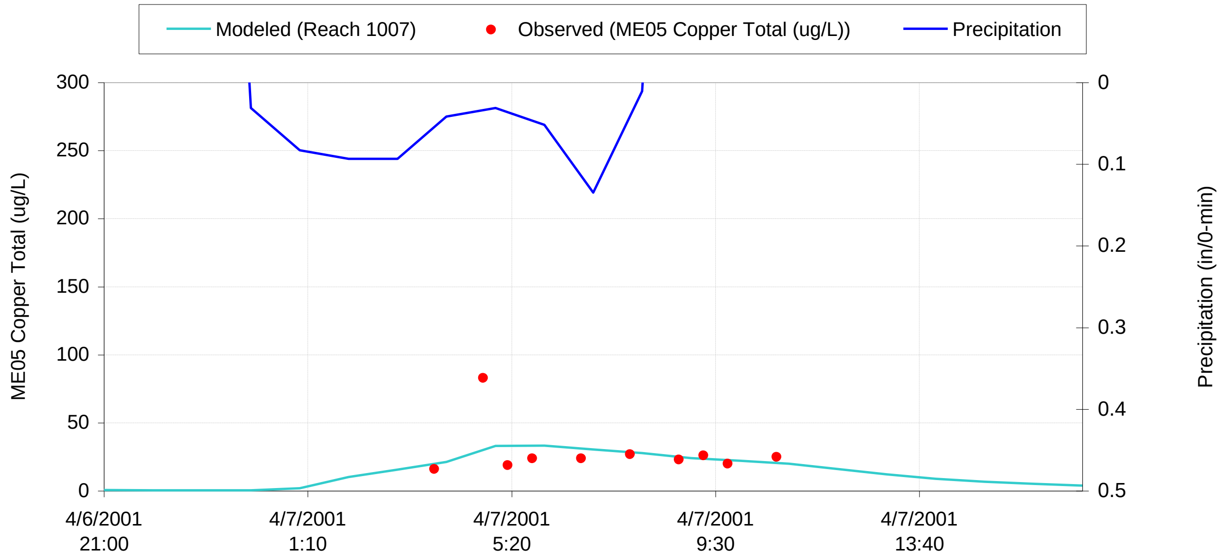


Figure 82. Modeled vs. observed ME05 Cu total (µg/L) at subbasin 1007.

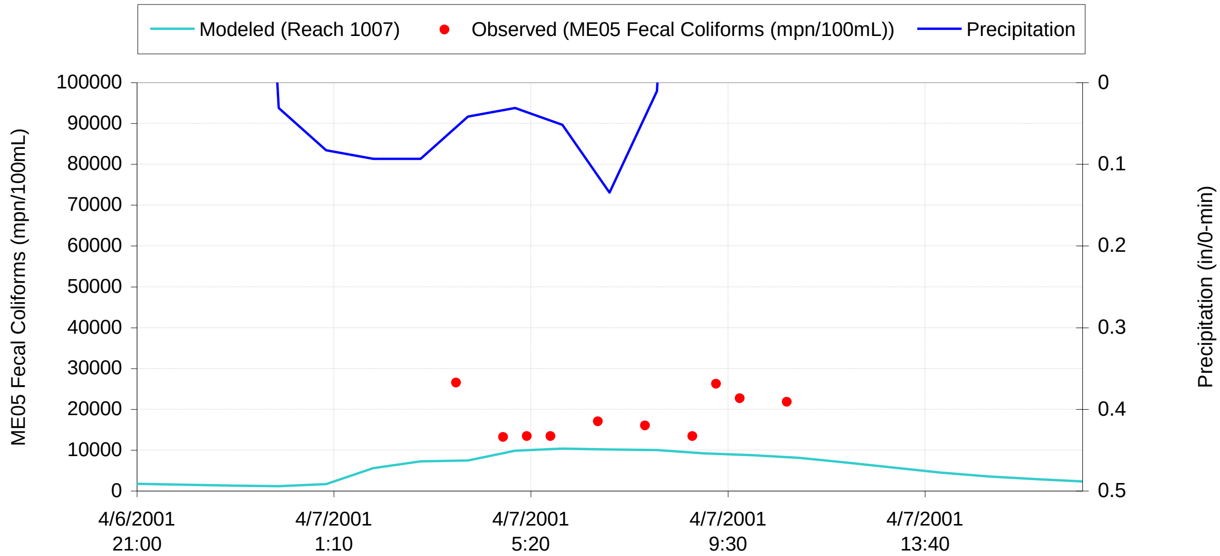


Figure 83. Modeled vs. observed ME05 fecal coliform (mpn/100mL) at subbasin 1007.

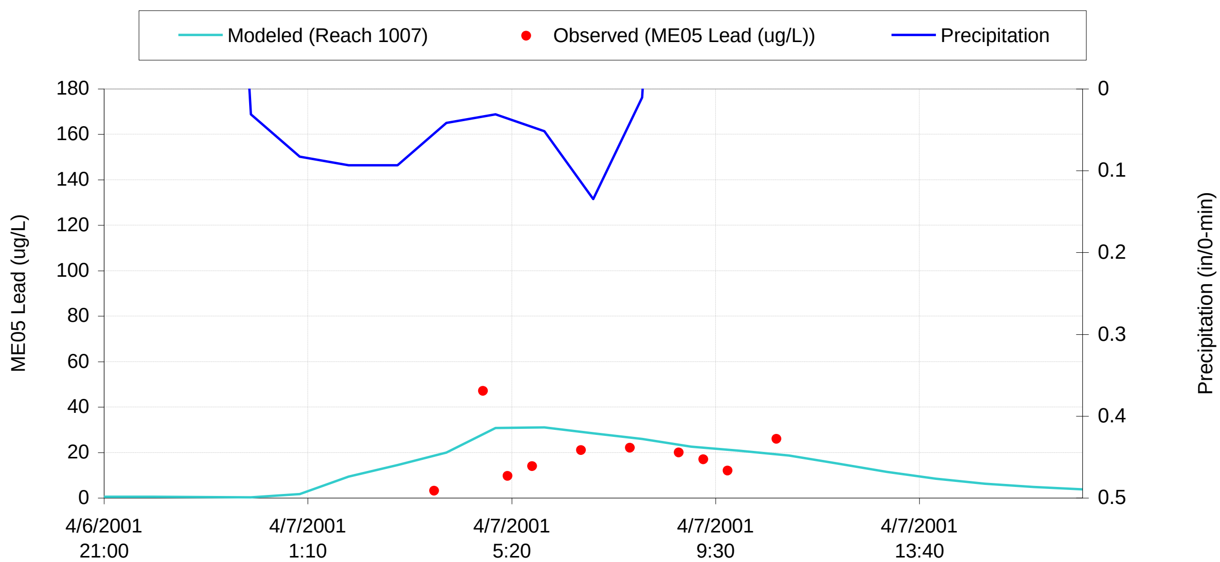


Figure 84. Modeled vs. observed ME05 Pb (µg/L) at subbasin 1007.

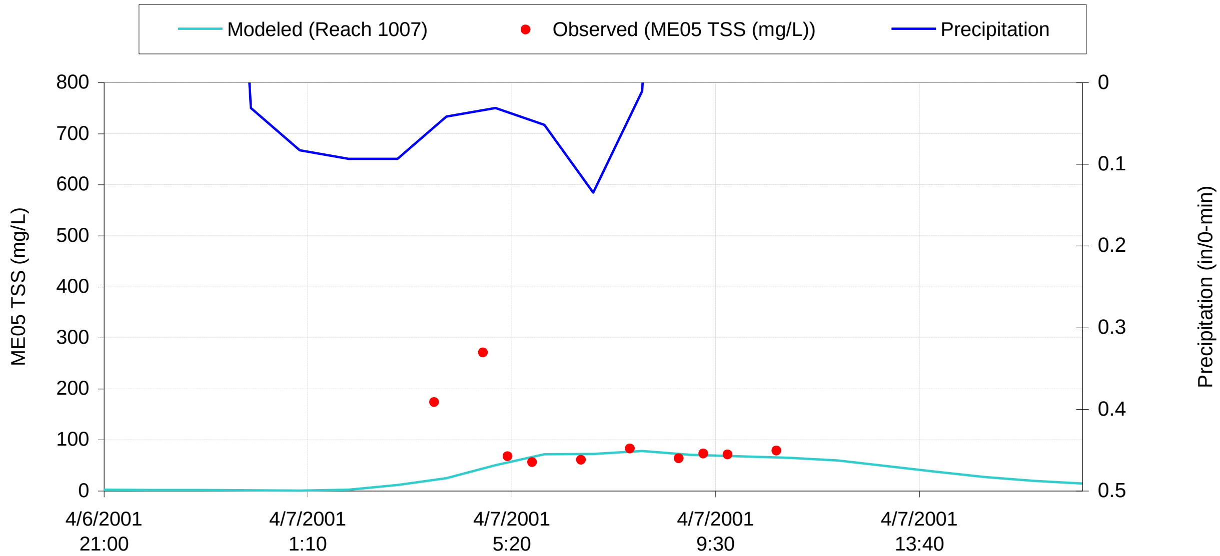


Figure 85. Modeled vs. observed ME05 TSS (mg/L) at subbasin 1007.

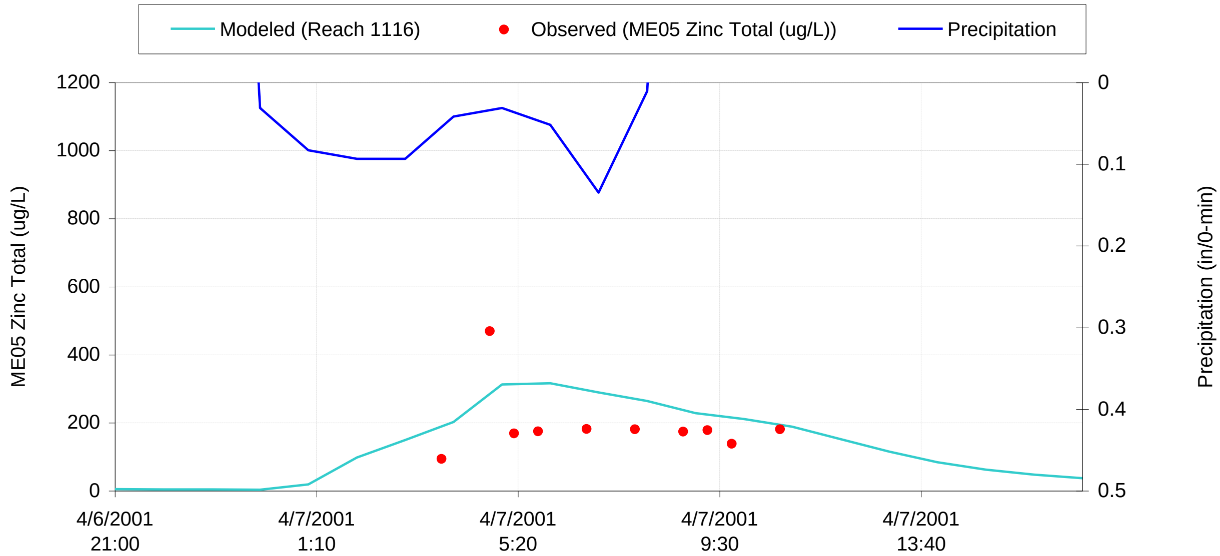


Figure 86. Modeled vs. observed ME05 Zn total (µg/L) at subbasin 1007.

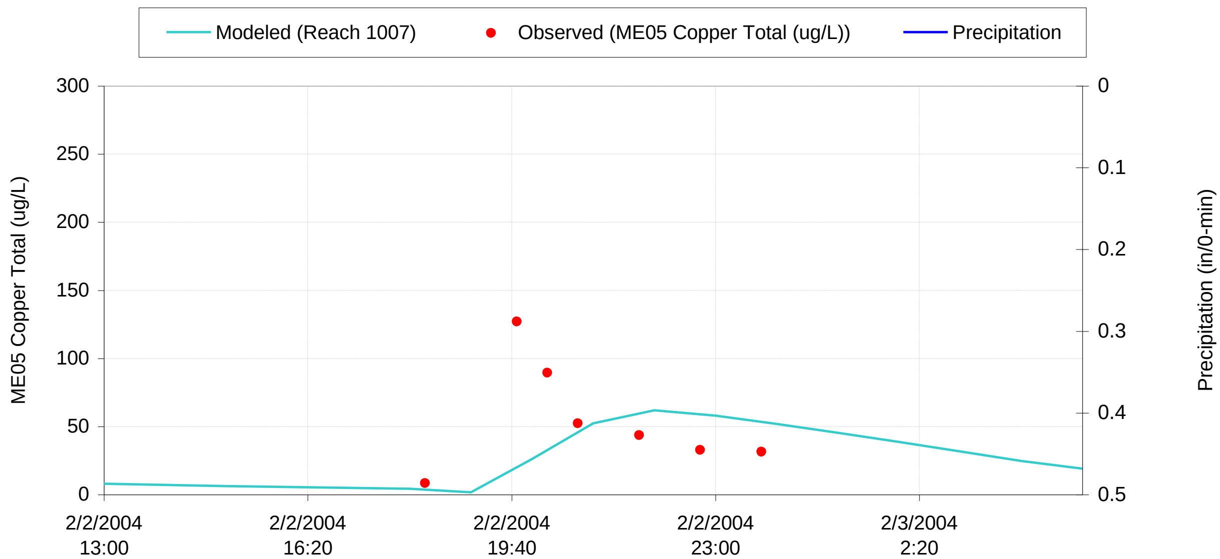


Figure 87. Modeled vs. observed ME05 Cu total (µg/L) at subbasin 1007.

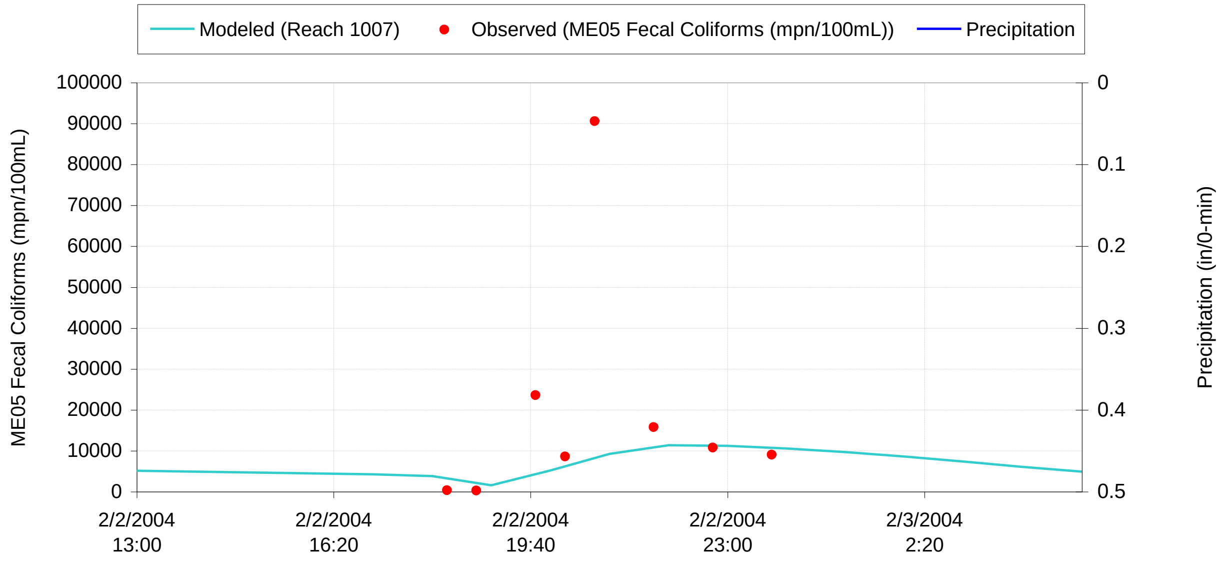


Figure 88. Modeled vs. observed ME05 fecal coliform (mpn/100mL) at subbasin 1007.

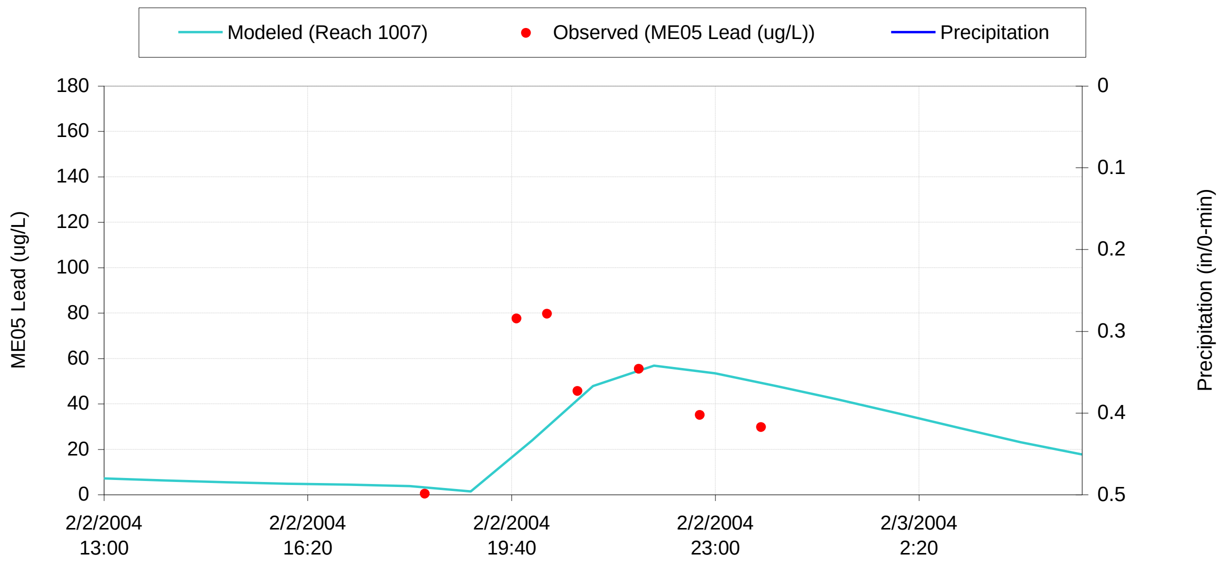


Figure 89. Modeled vs. observed ME05 Pb (µg/L) at subbasin 1007.

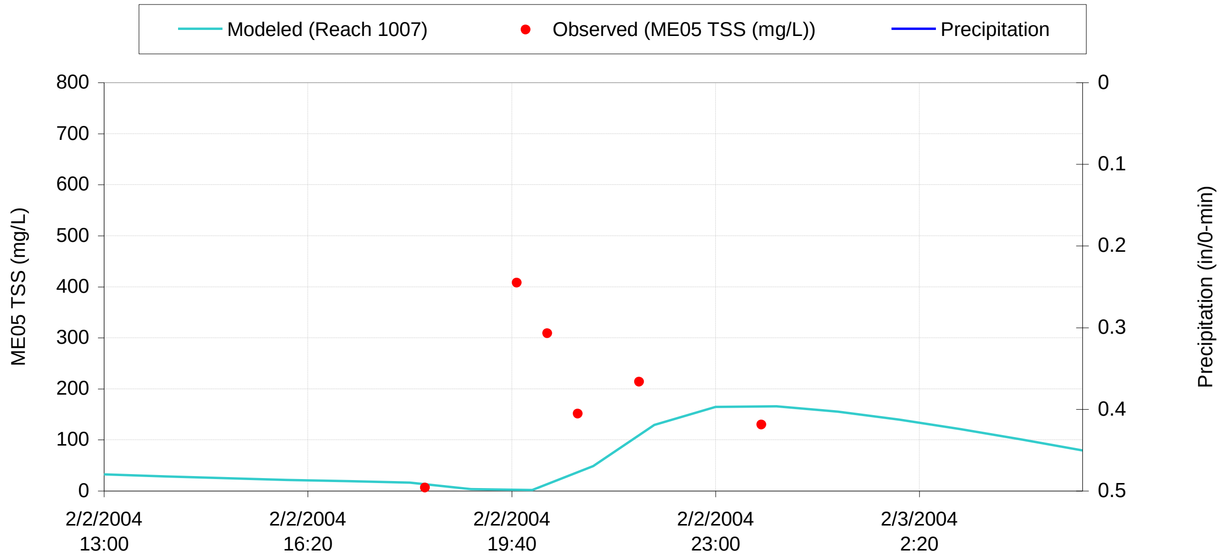


Figure 90. Modeled vs. observed ME05 TSS (mg/L) at subbasin 1007.

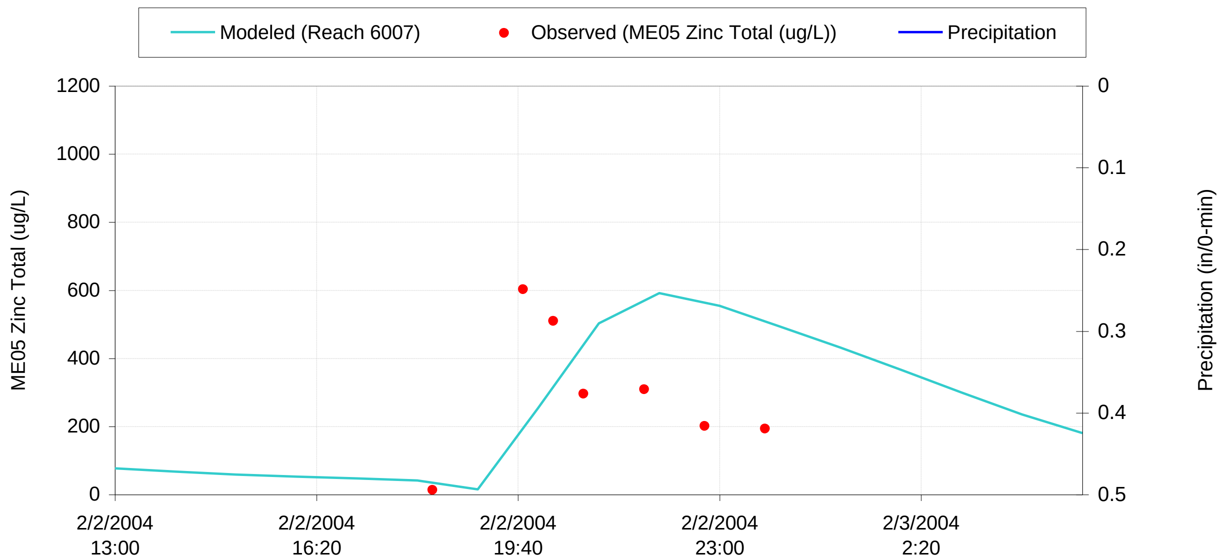


Figure 91. Modeled vs. observed ME05 Zn total (µg/L) at subbasin 1007.

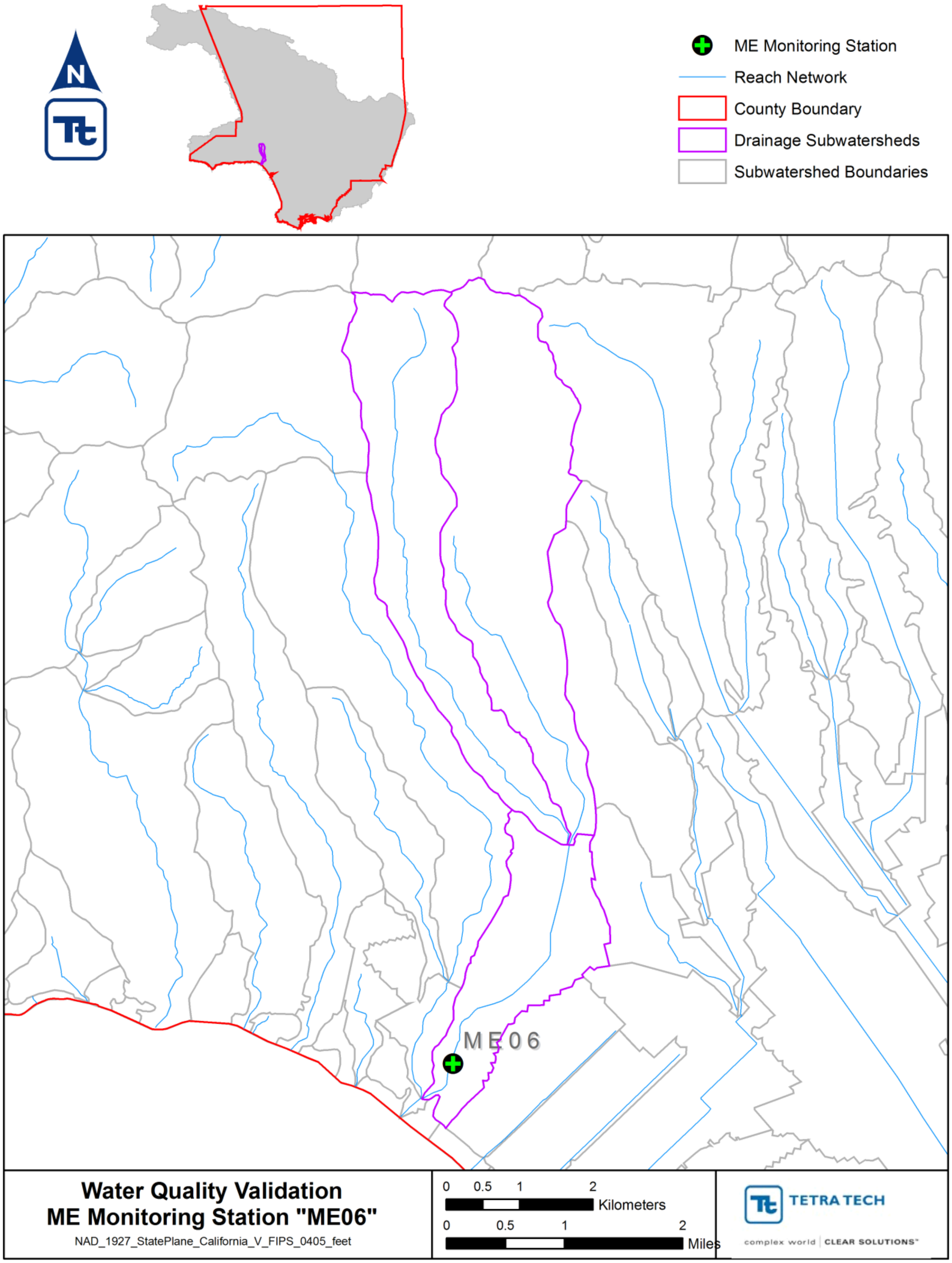


Figure 92. Location and drainage areas of mass emission site ME06.

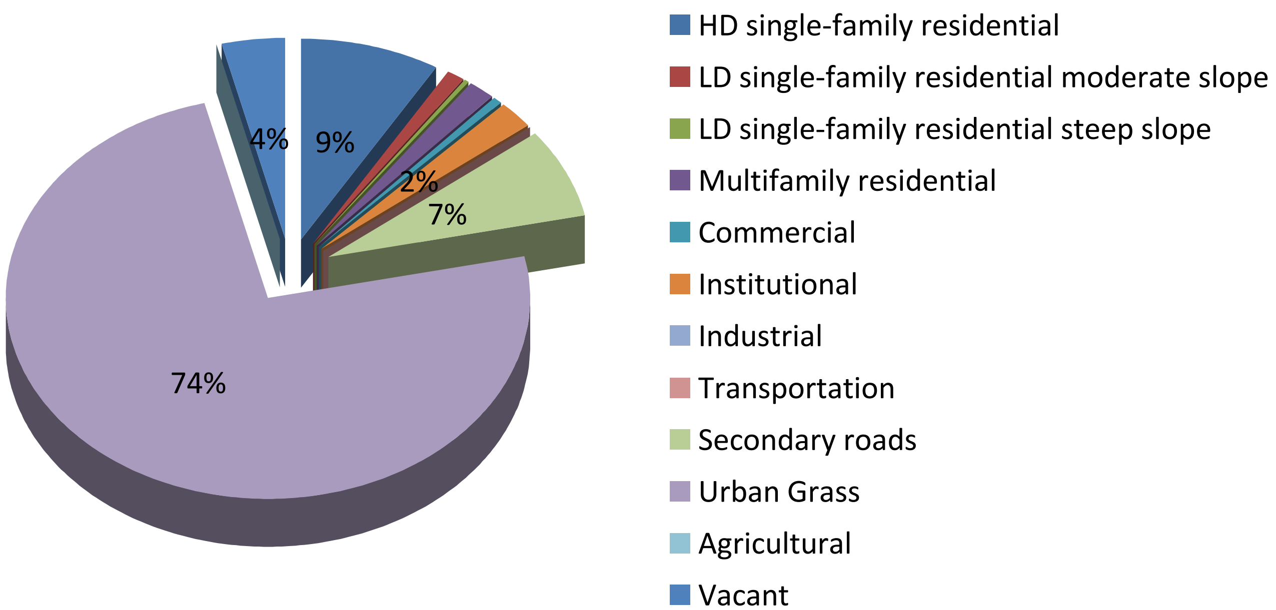


Figure 93. Land use distribution upstream of mass emission site ME06.

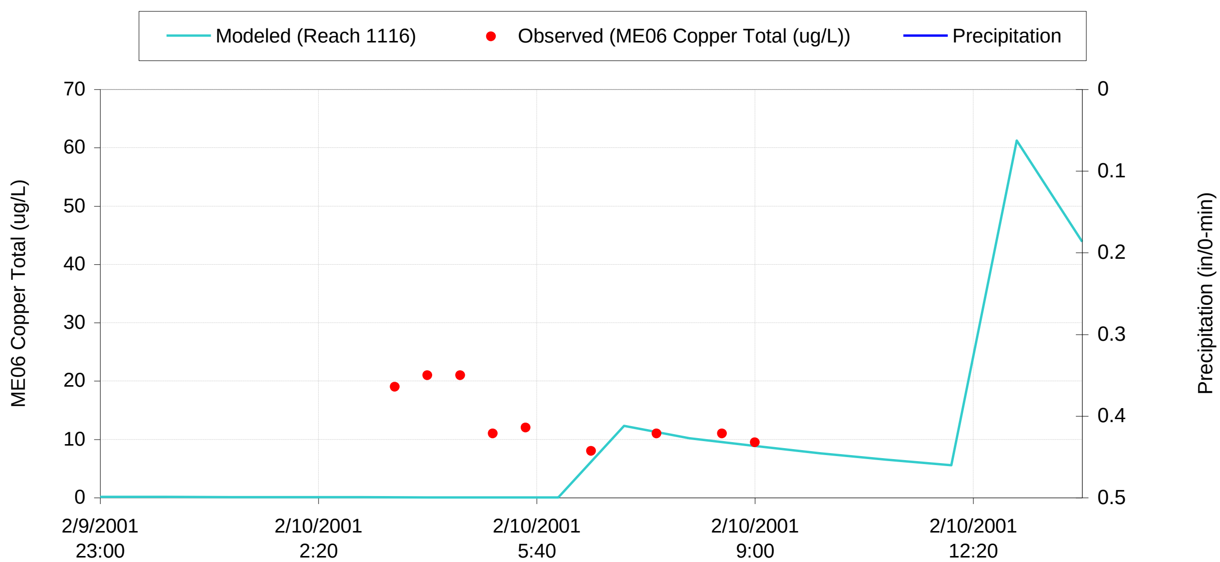


Figure 94. Modeled vs. observed ME06 Cu total (µg/L) at subbasin 1116.

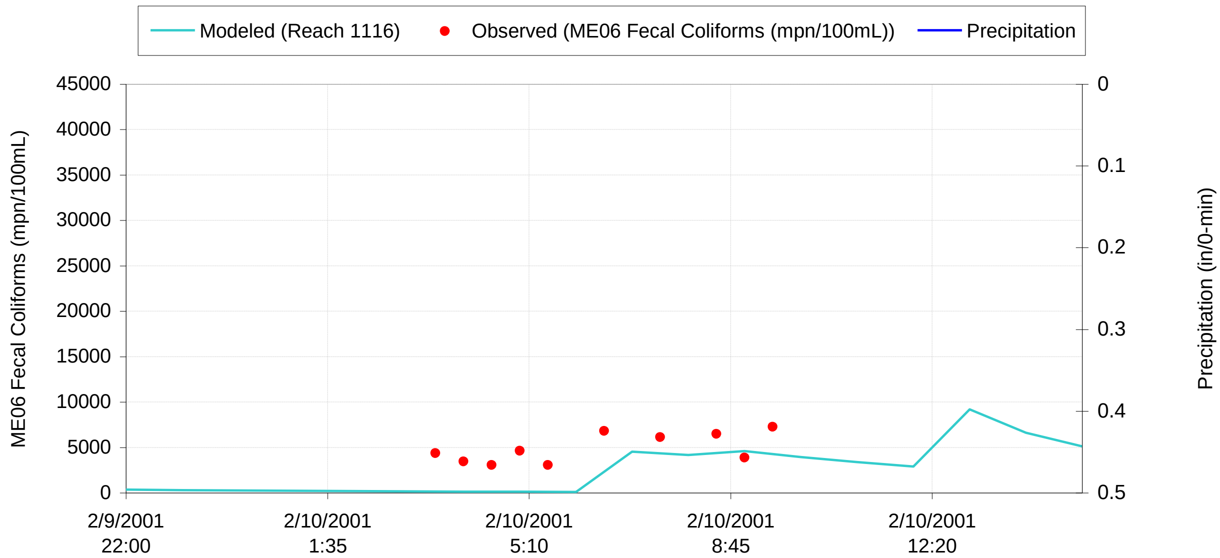


Figure 95. Modeled vs. observed ME06 fecal coliform (mpn/100mL) at subbasin 1116.

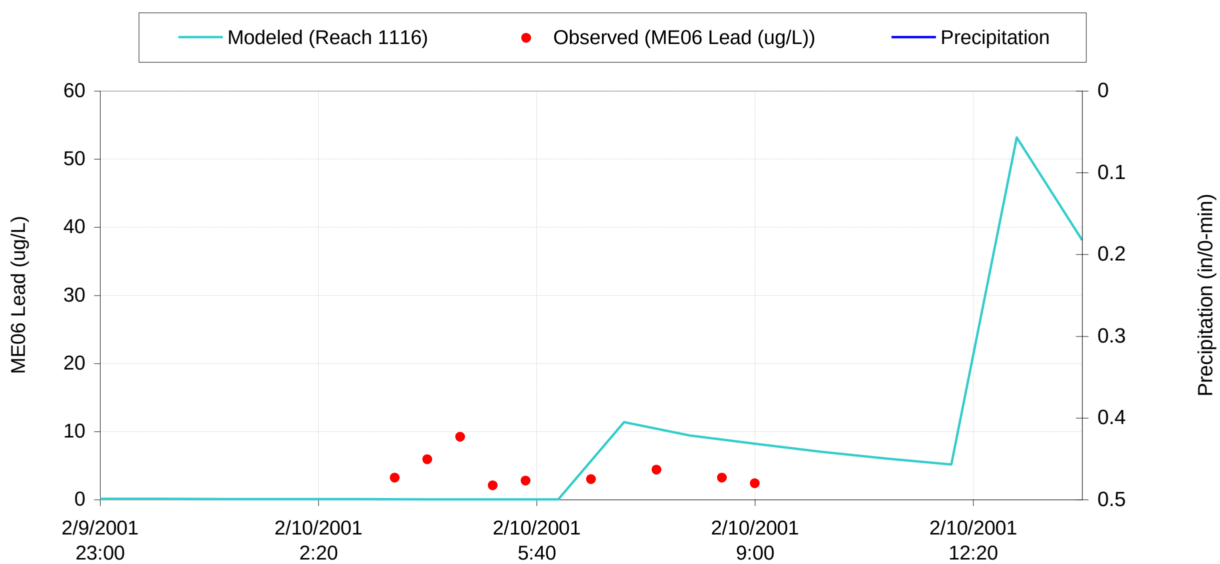


Figure 96. Modeled vs. observed ME06 Pb (µg/L) at subbasin 1116.

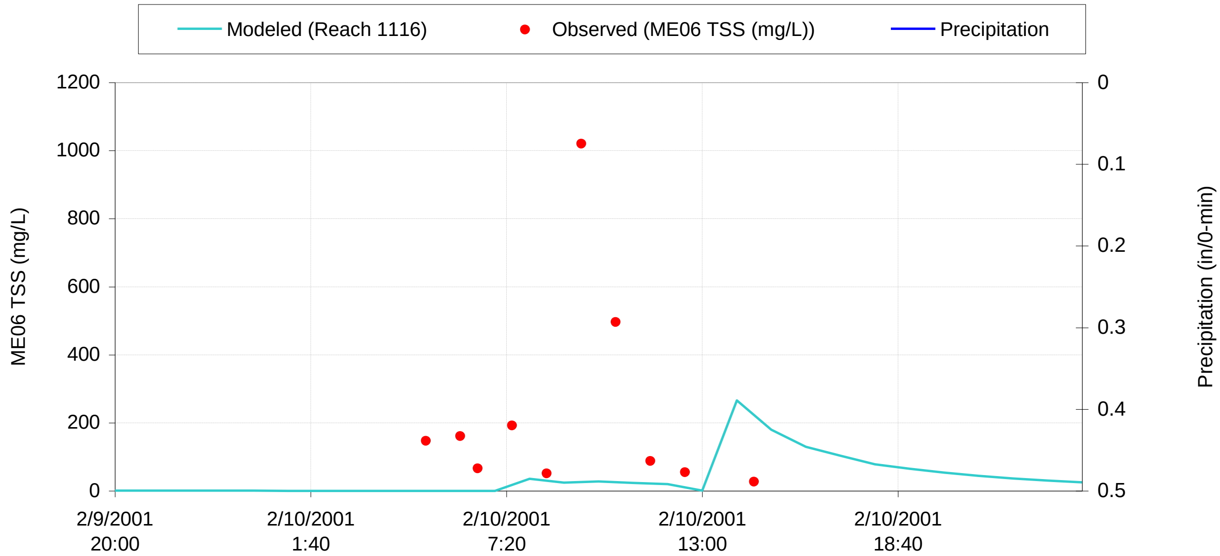


Figure 97. Modeled vs. observed ME06 TSS (mg/L) at subbasin 1116.

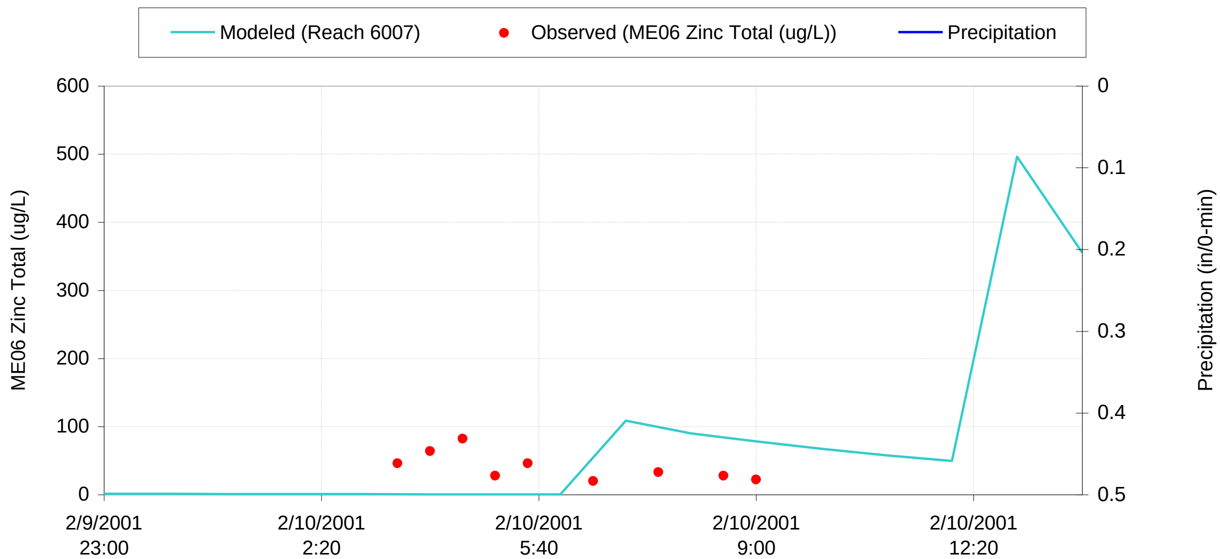


Figure 98. Modeled vs. observed ME06 Zn total (μg/L) at subbasin 1116.

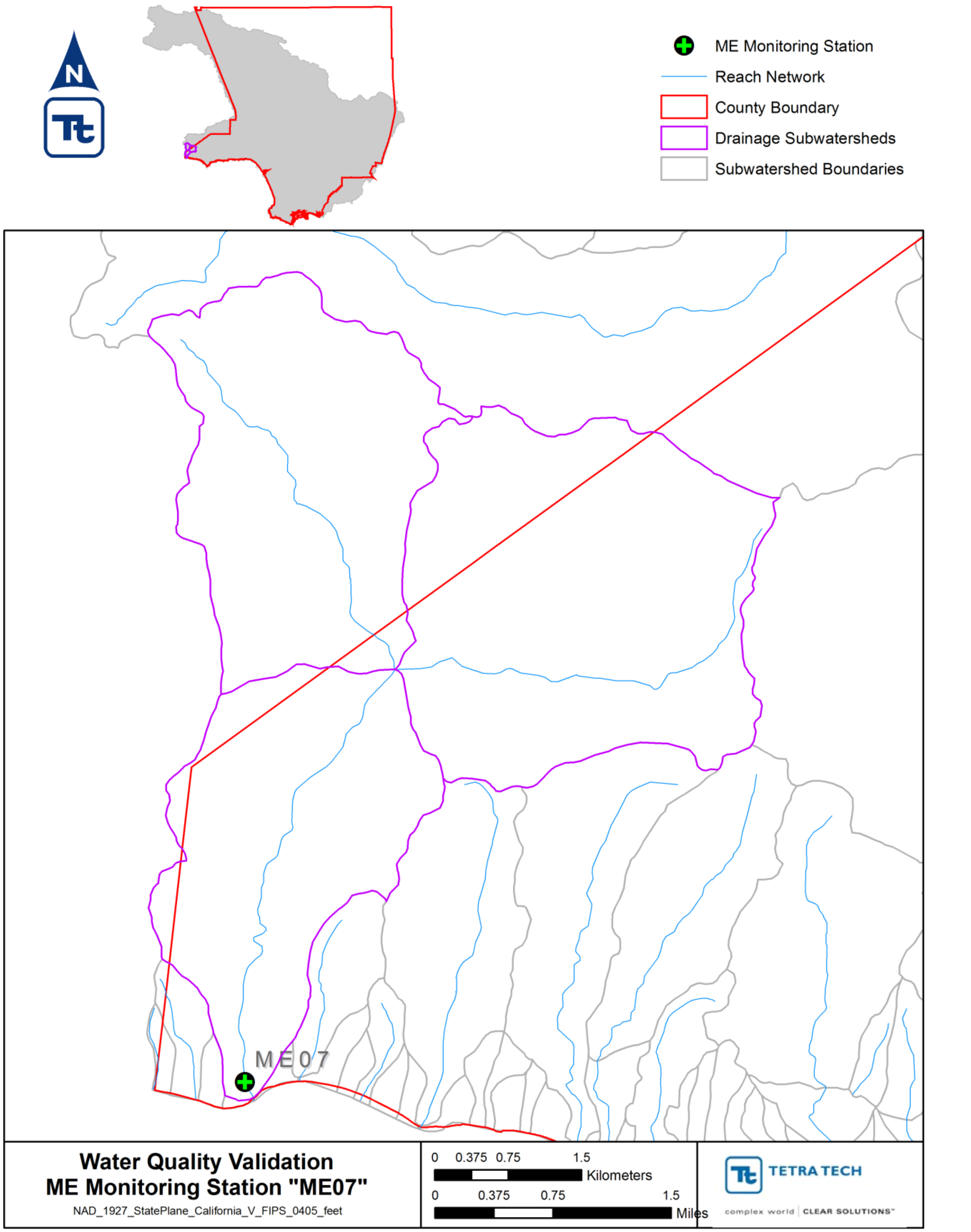


Figure 99. Location and drainage areas of mass emission site ME07.

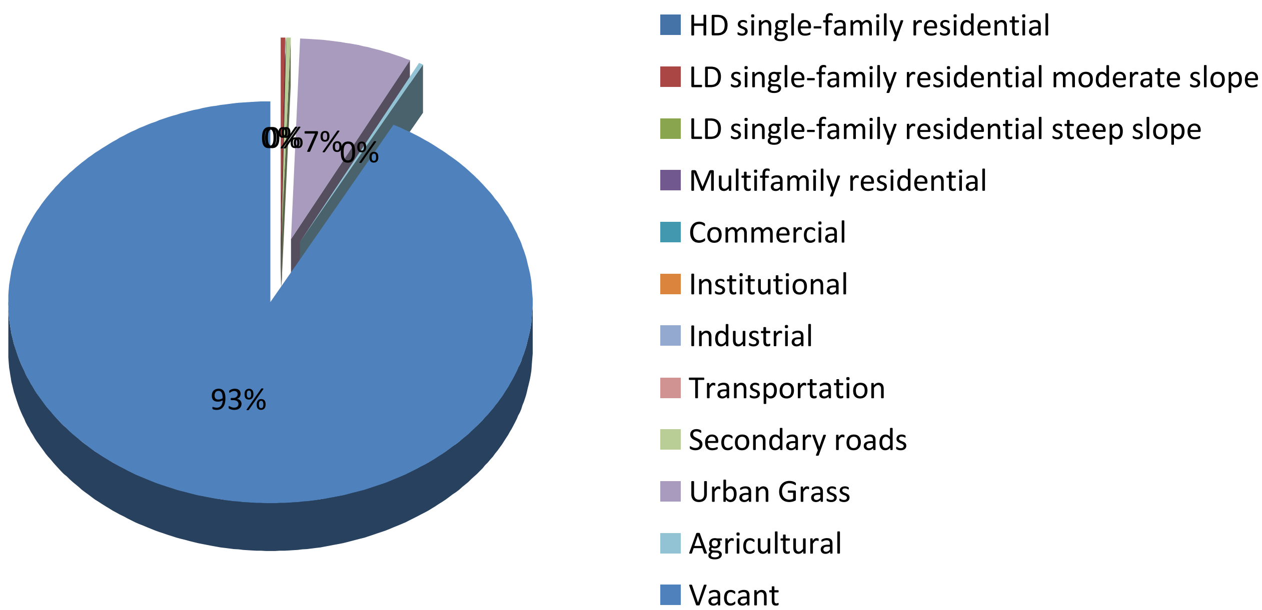


Figure 100. Land use distribution upstream of mass emission site ME07.

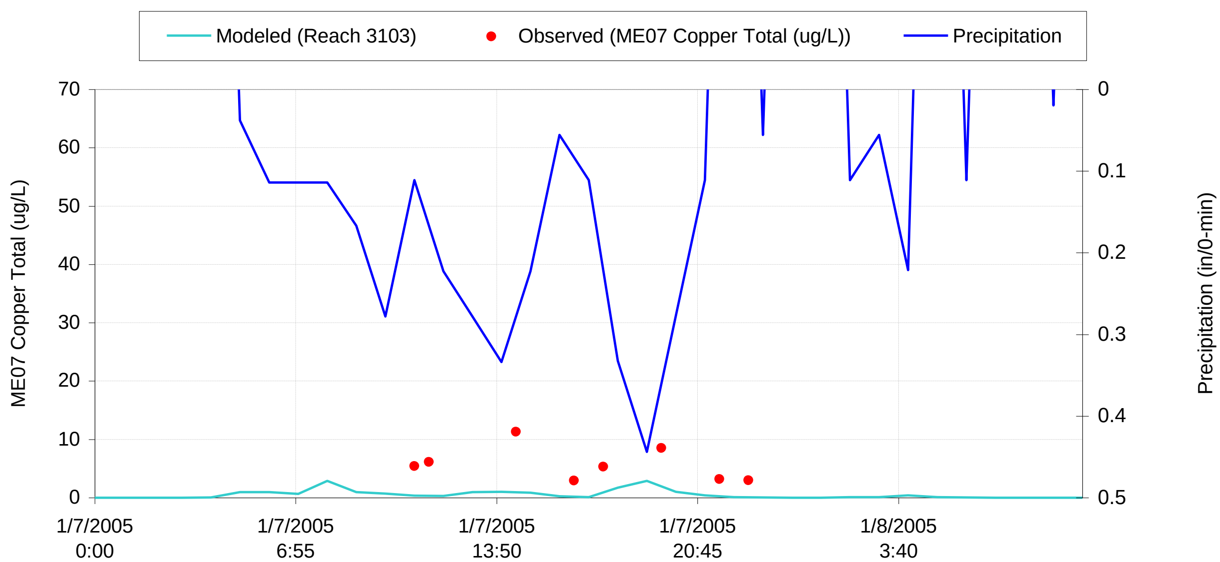


Figure 101. Modeled vs. observed ME07 Cu total (µg/L) at subbasin 3103.

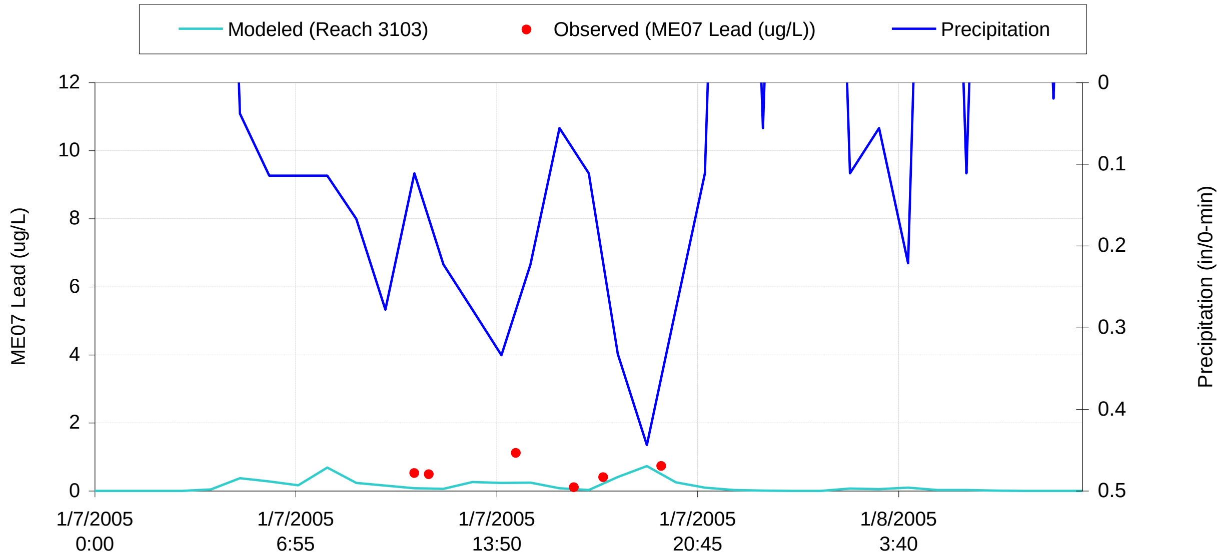


Figure 102. Modeled vs. observed ME07 Pb (µg/L) at subbasin 3103.

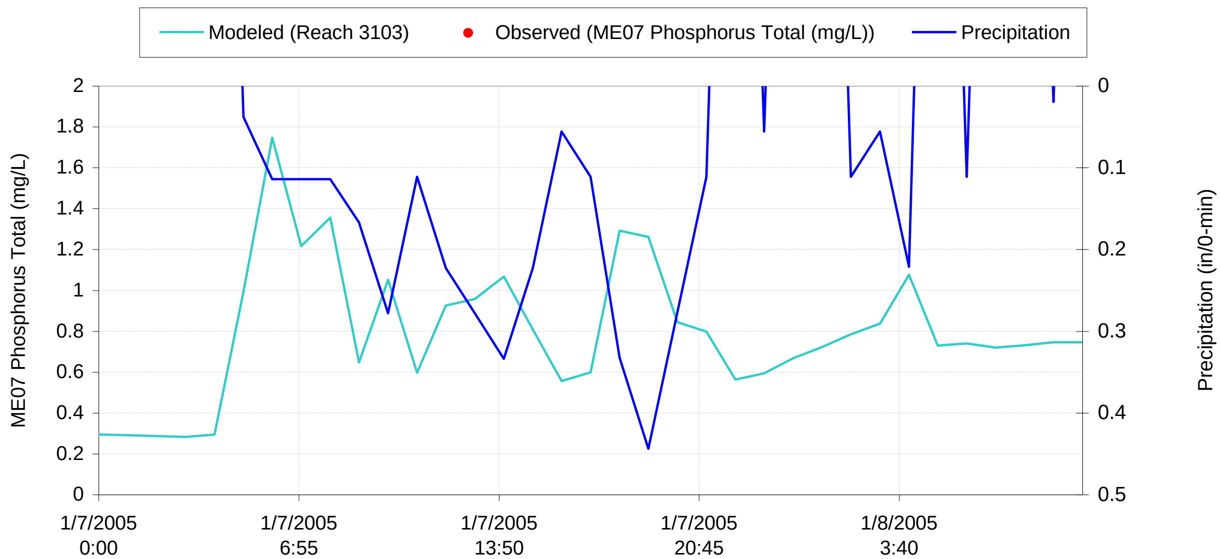


Figure 103. Modeled vs. observed ME07 phosphorus total (mg/L) at subbasin 3103.

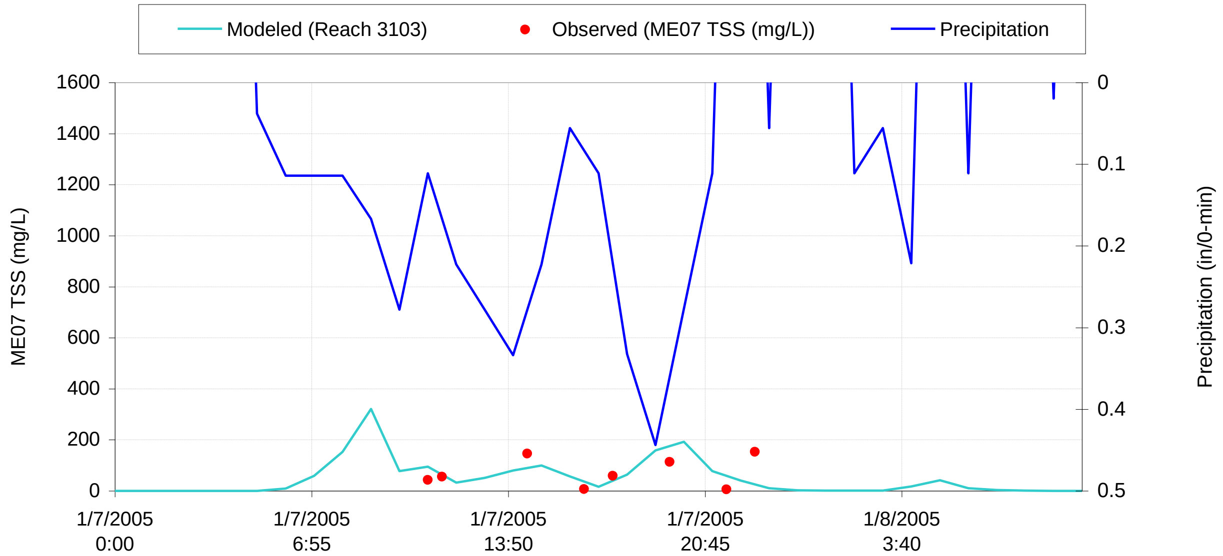


Figure 104. Modeled vs. observed ME07 TSS (mg/L) at subbasin 3103.

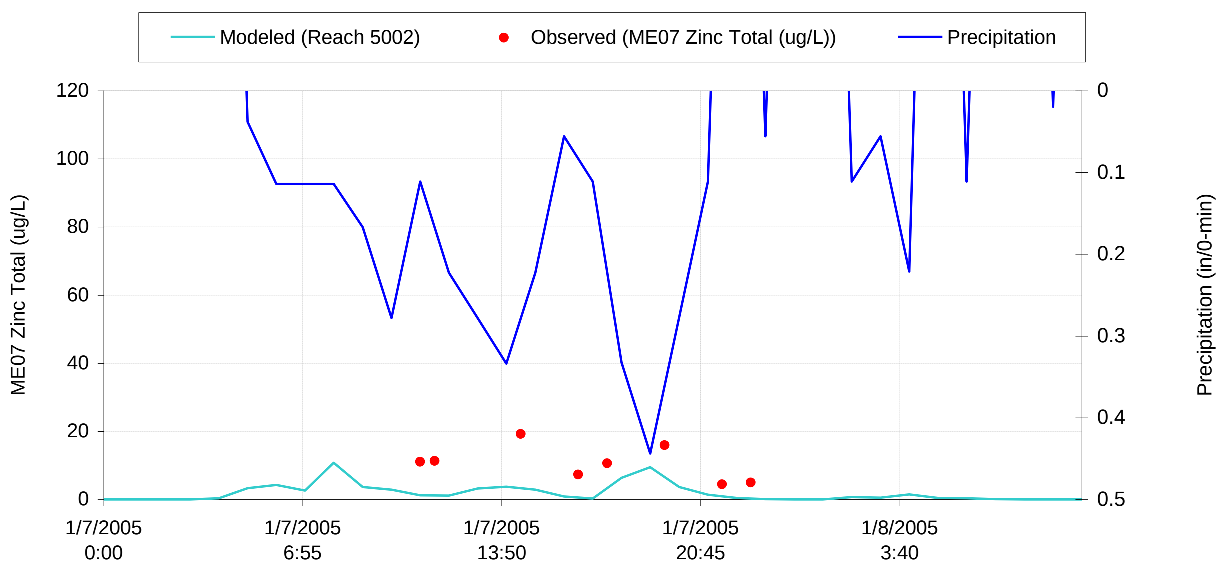


Figure 105. Modeled vs. observed ME07 Zn total (µg/L) at subbasin 3103.

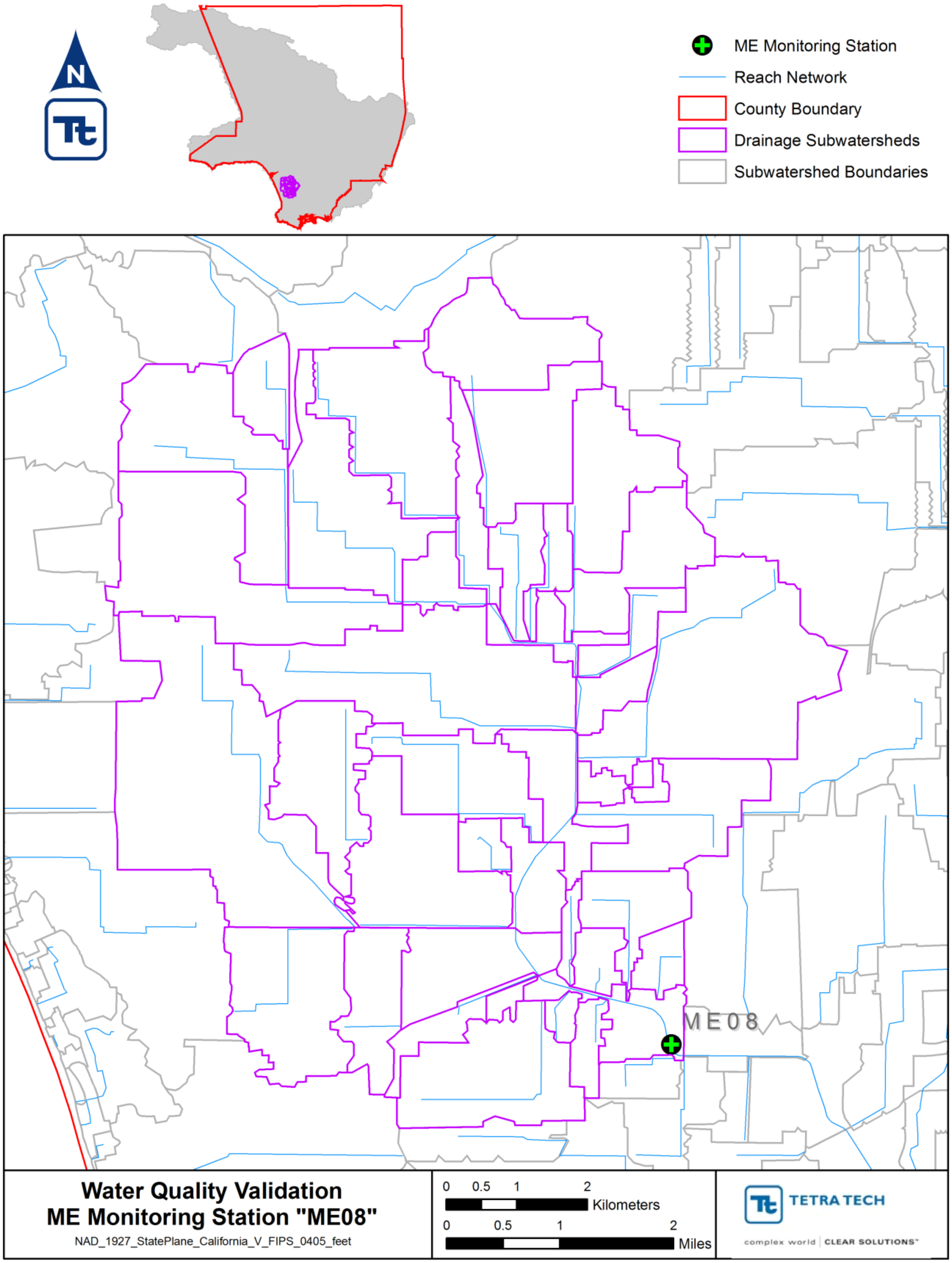


Figure 106. Location and drainage areas of mass emission site ME08.

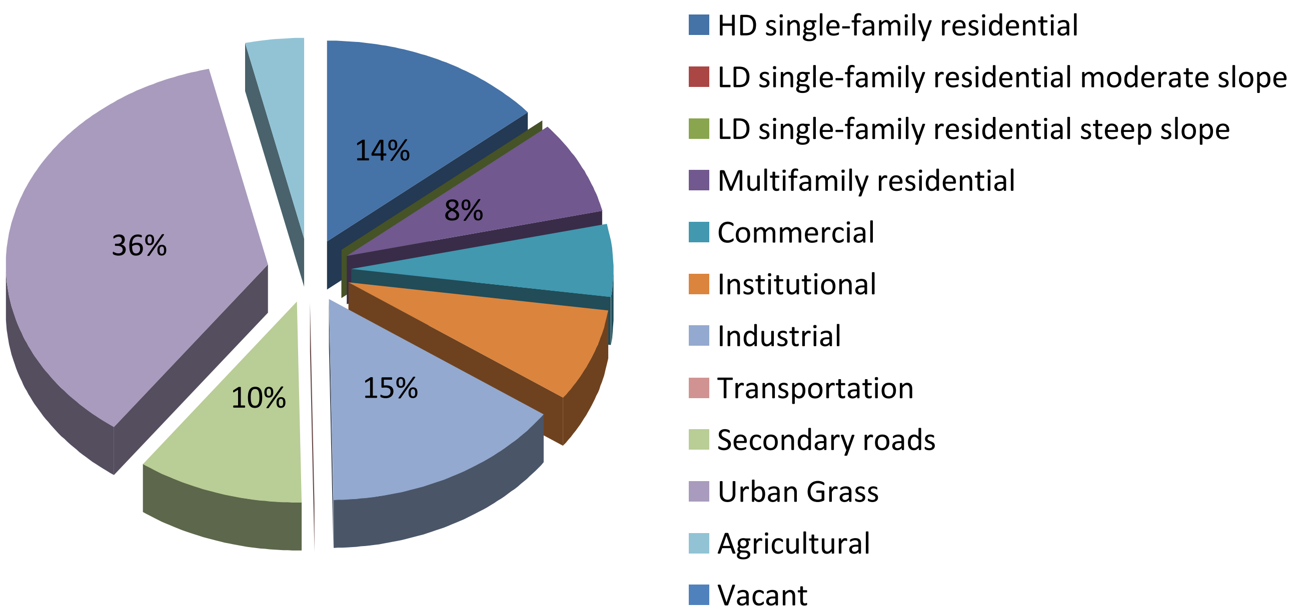


Figure 107. Land use distribution upstream of mass emission site ME08.

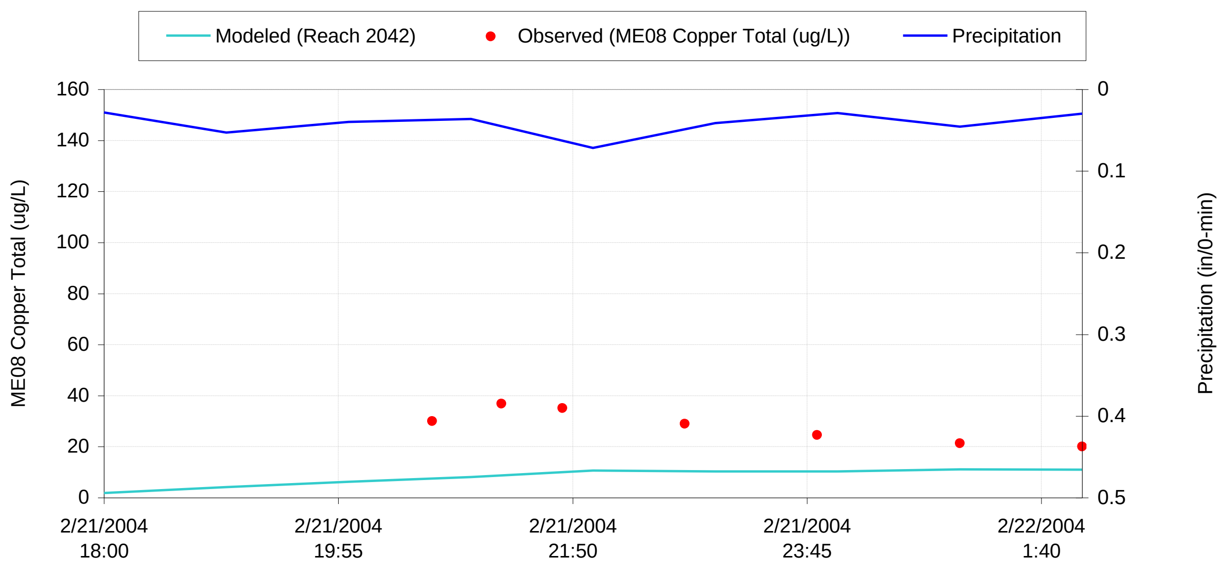


Figure 108. Modeled vs. observed ME08 Cu total (µg/L) at subbasin 2042.

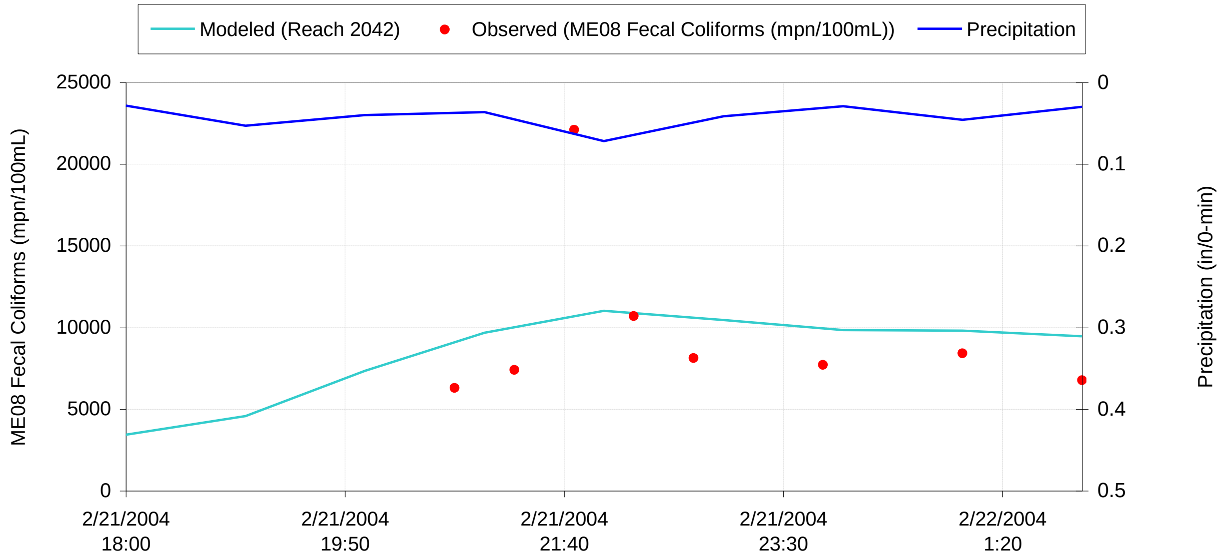


Figure 109. Modeled vs. observed ME08 fecal coliform (mpn/100mL) at subbasin 2042.

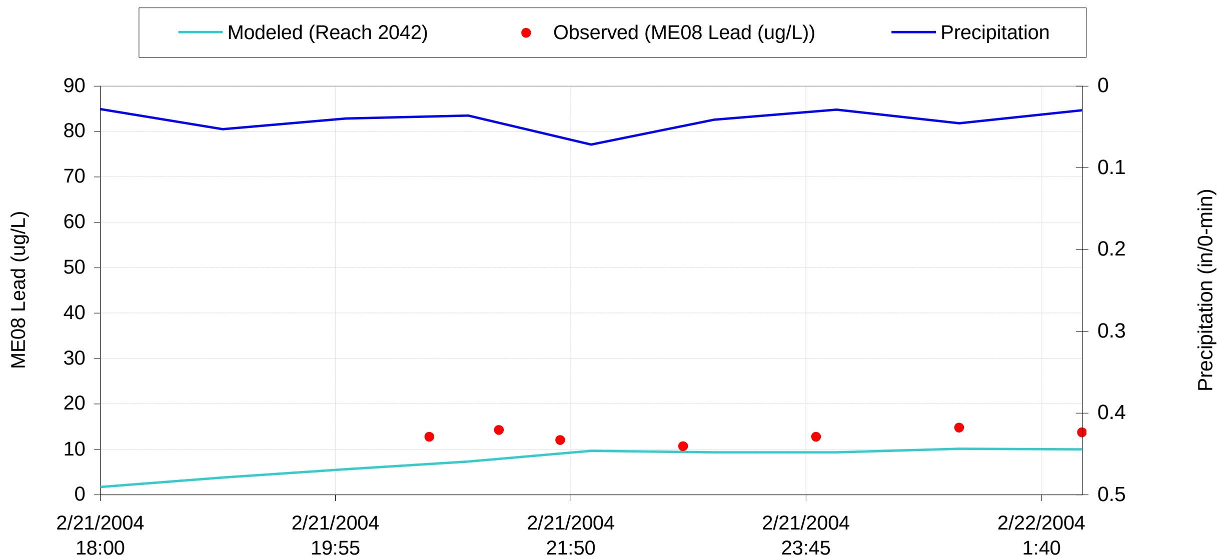


Figure 110. Modeled vs. observed ME08 Pb (µg/L) at subbasin 2042.

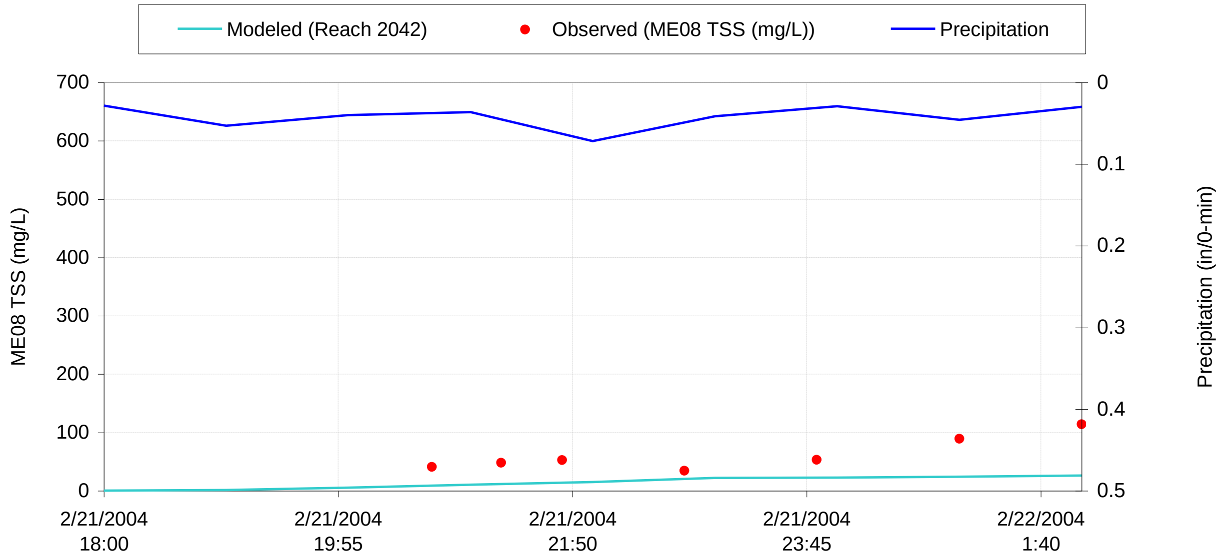


Figure 111. Modeled vs. observed ME08 TSS (mg/L) at subbasin 2042.

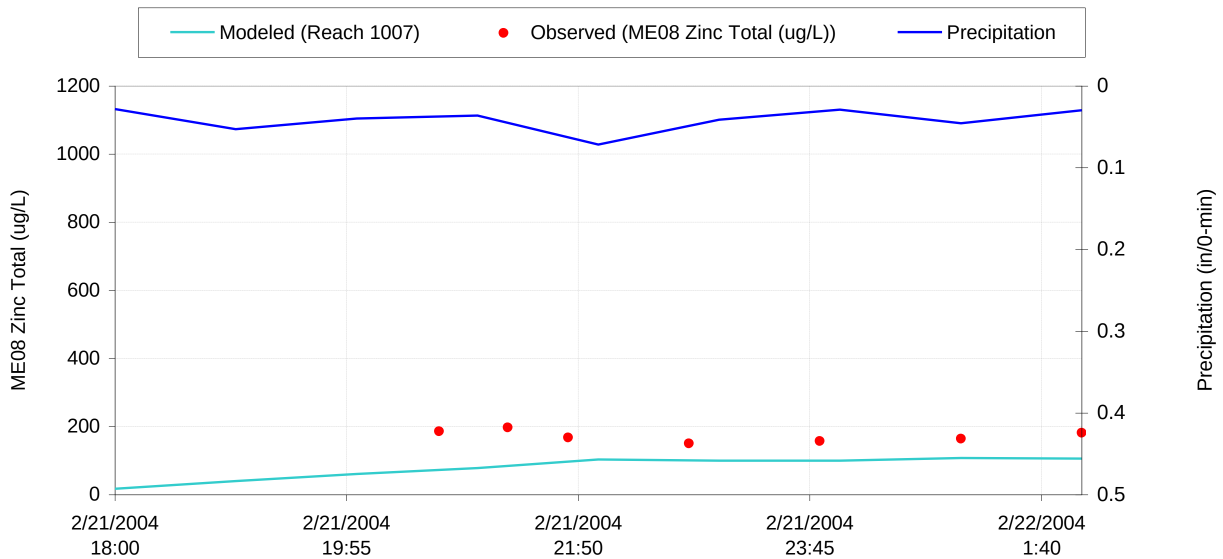


Figure 112. Modeled vs. observed ME08 Zn total (µg/L) at subbasin 2042.

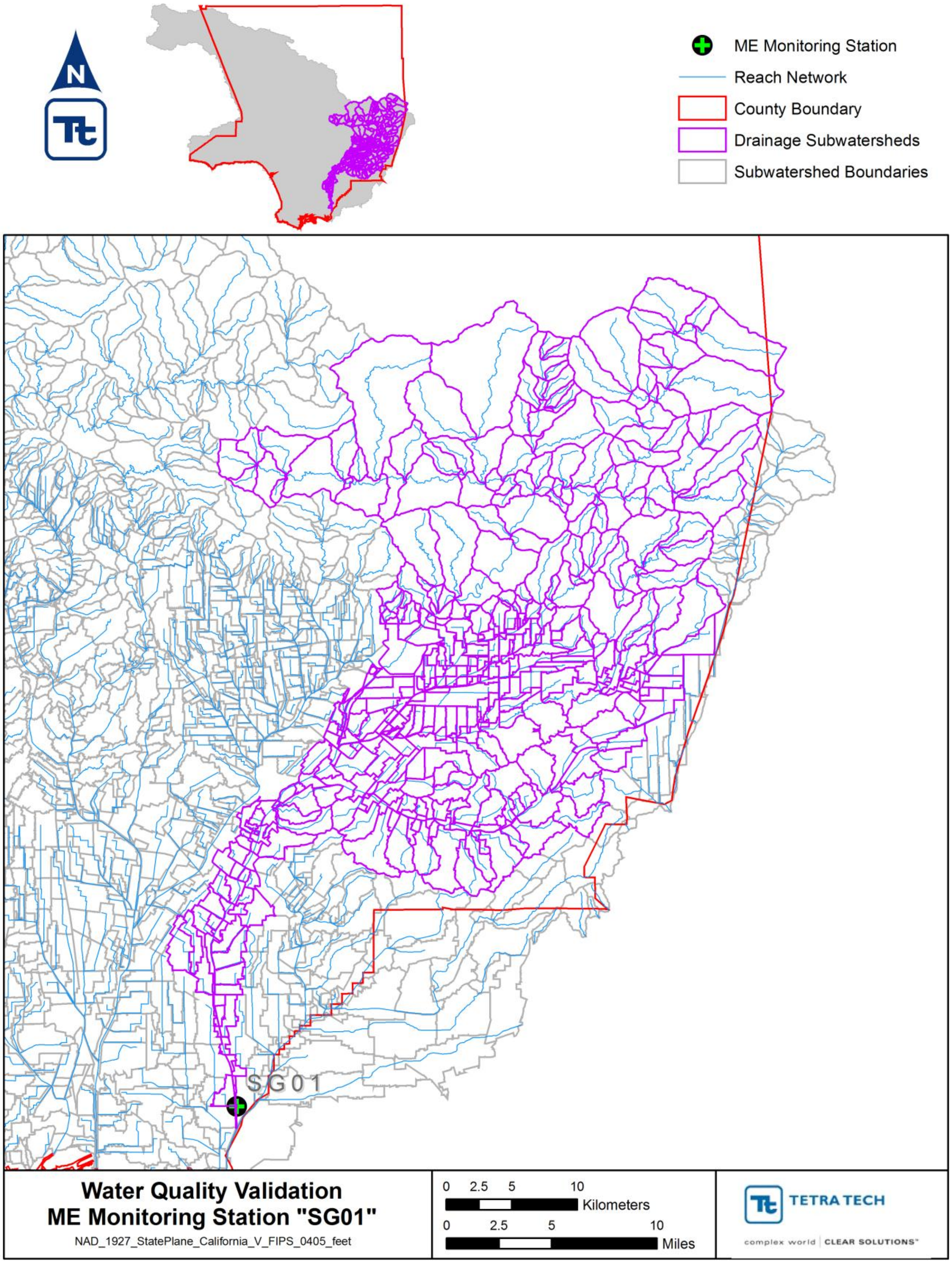


Figure 113. Location and drainage areas of mass emission site SG01.

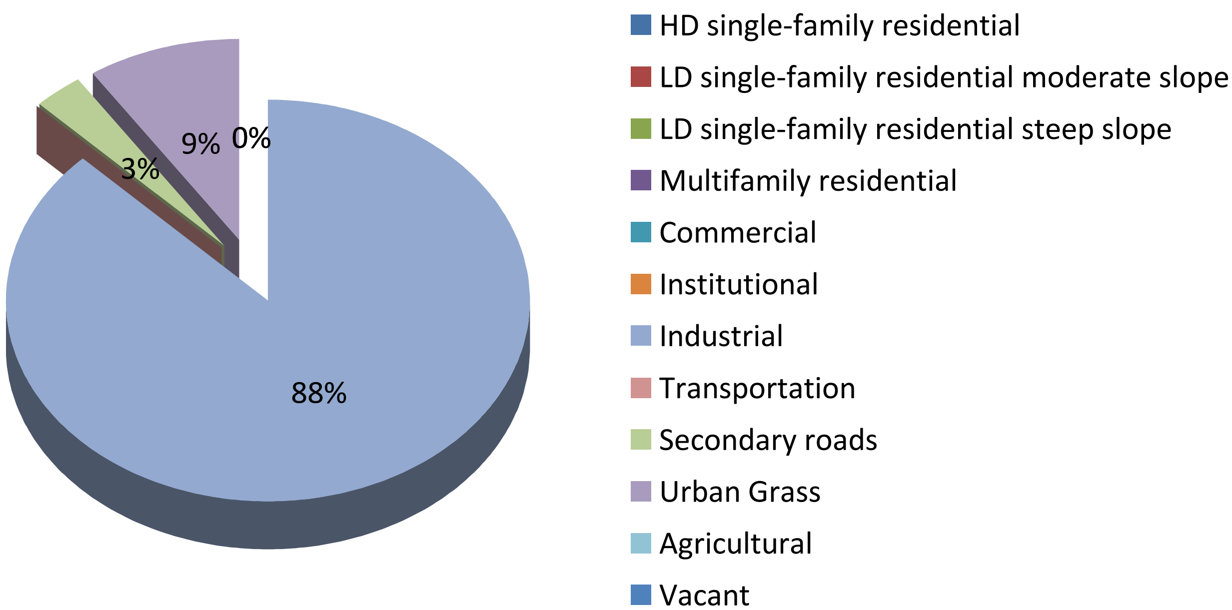


Figure 114. Land use distribution upstream of mass emission site SG01.

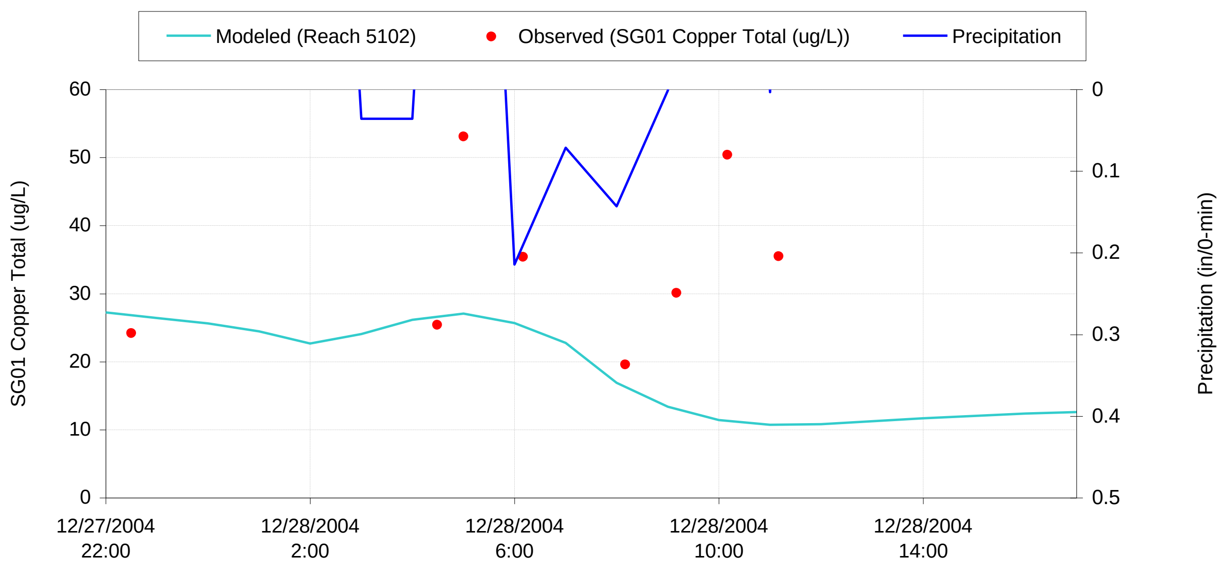


Figure 115. Modeled vs. observed SG01 Cu total (µg/L) at subbasin 5102.

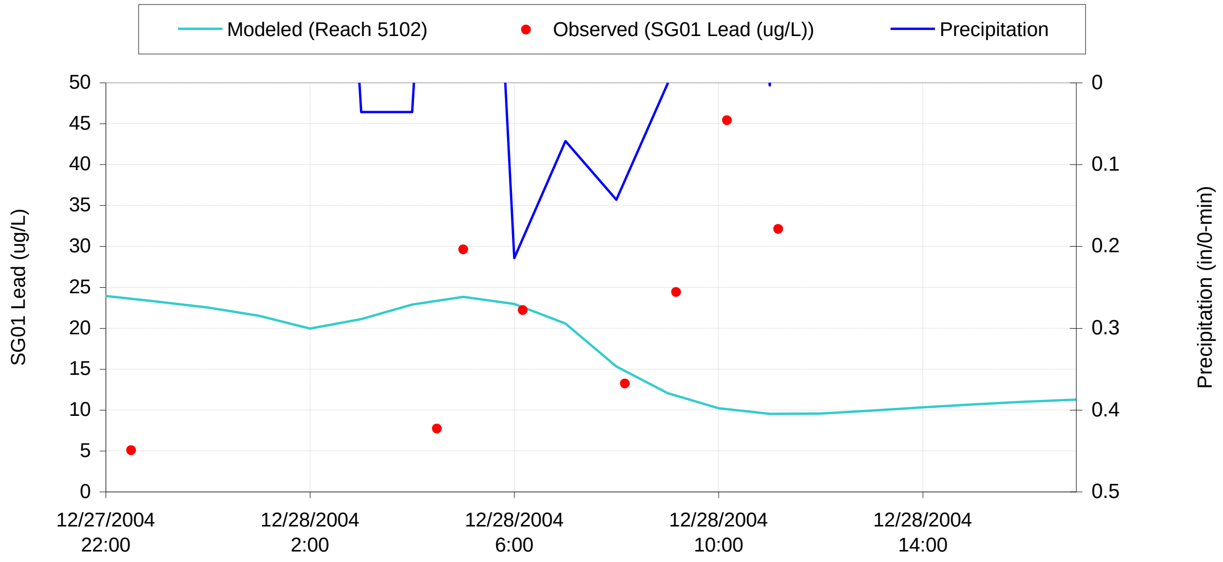


Figure 116. Modeled vs. observed SG01 Pb (µg/L) at subbasin 5102.

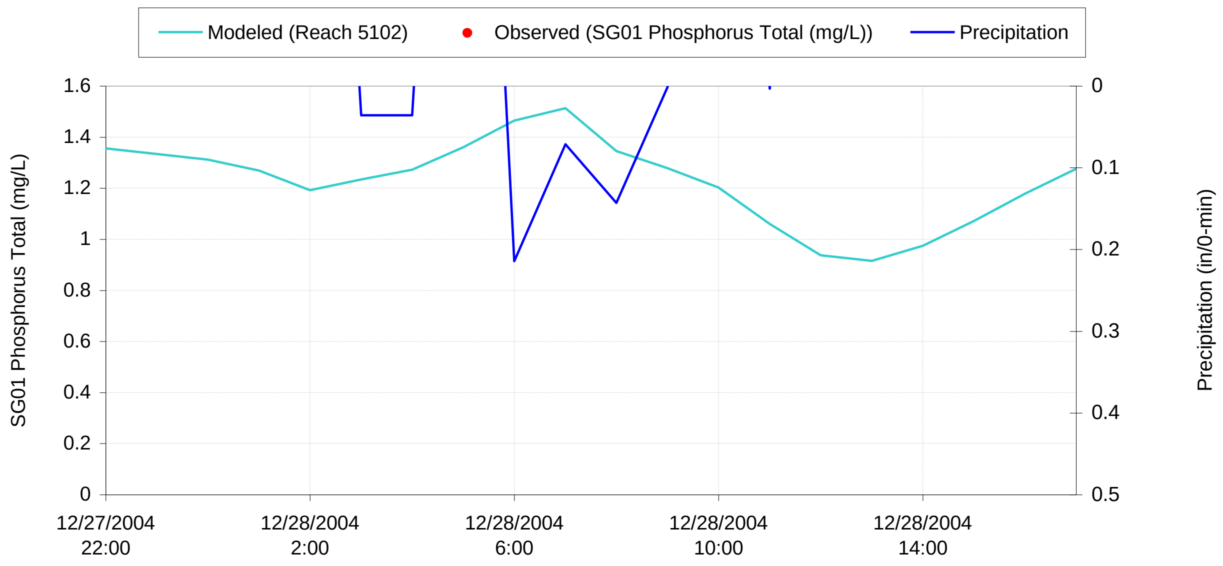


Figure 117. Modeled vs. observed SG01 phosphorus total (mg/L) at subbasin 5102.

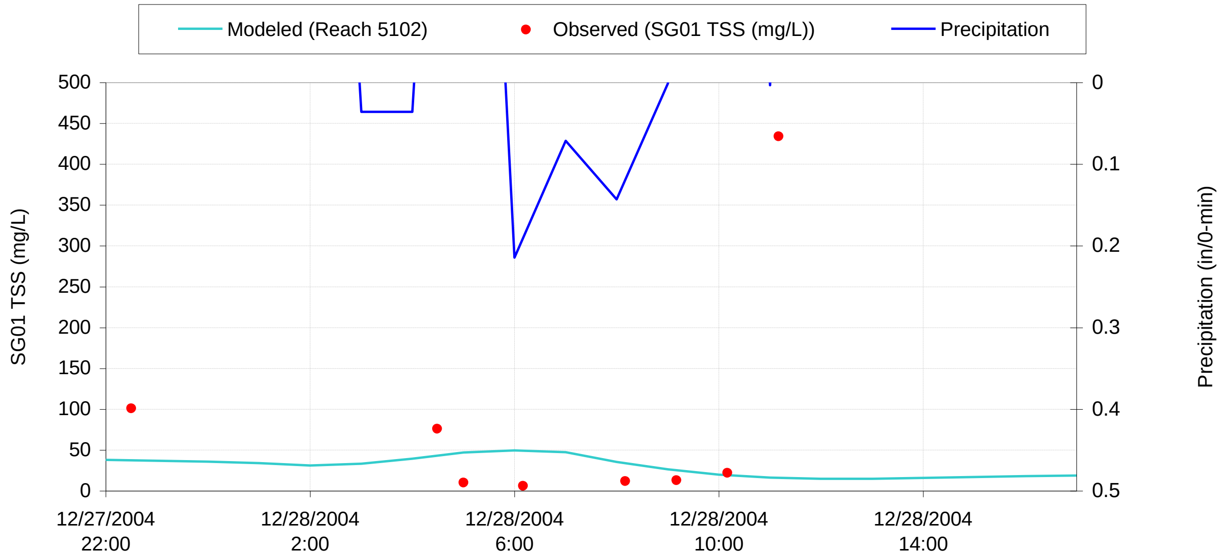


Figure 118. Modeled vs. observed SG01 TSS (mg/L) at subbasin 5102.

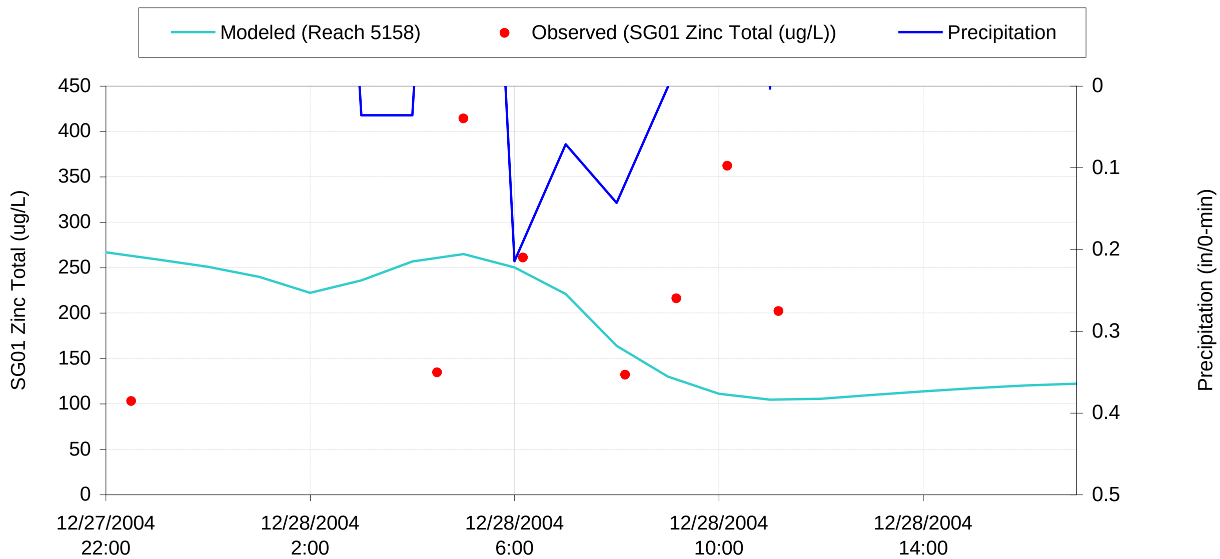


Figure 119. Modeled vs. observed SG01 Zn total (µg/L) at subbasin 5102.

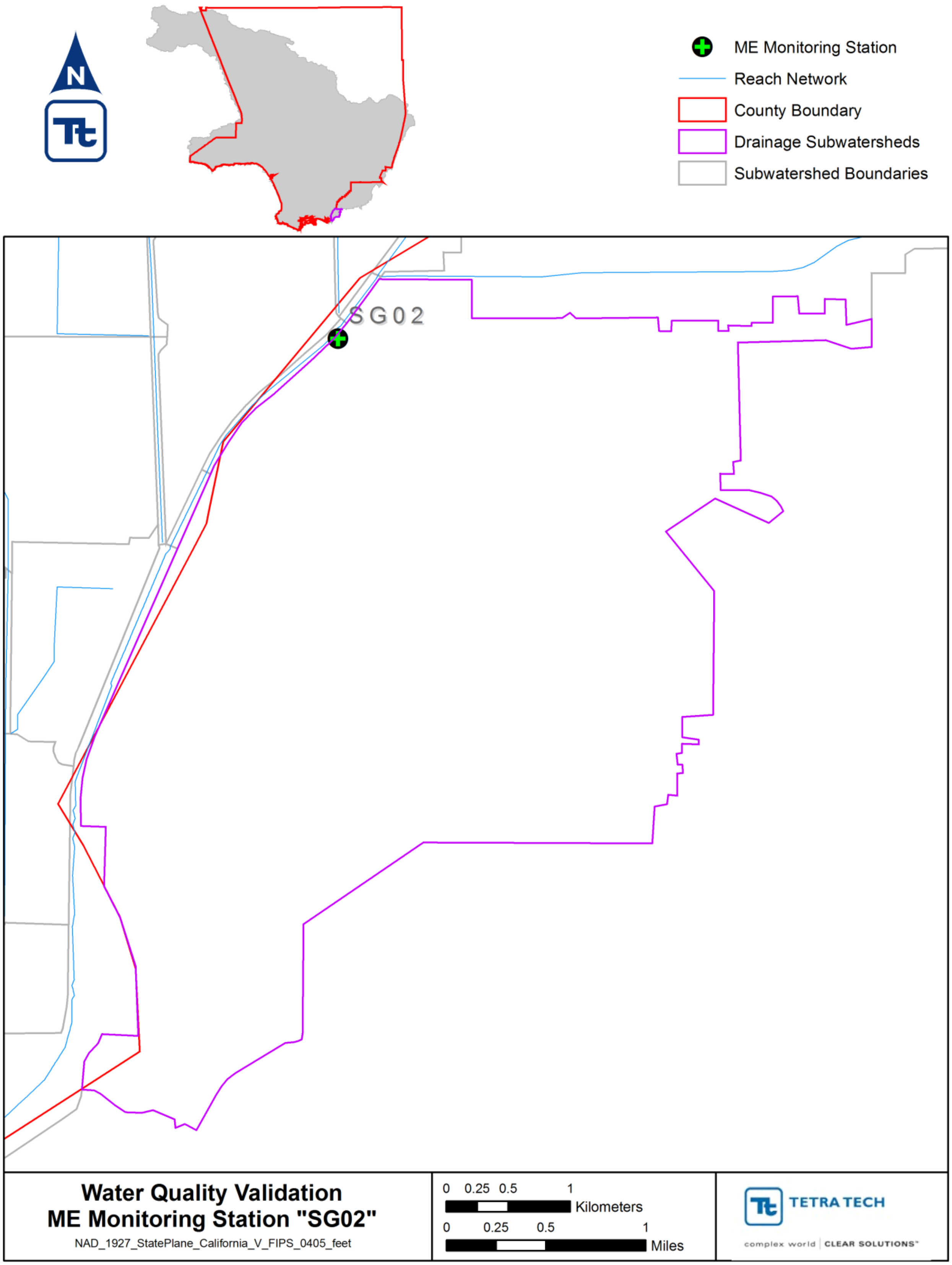


Figure 120. Location and drainage areas of mass emission site SG02.

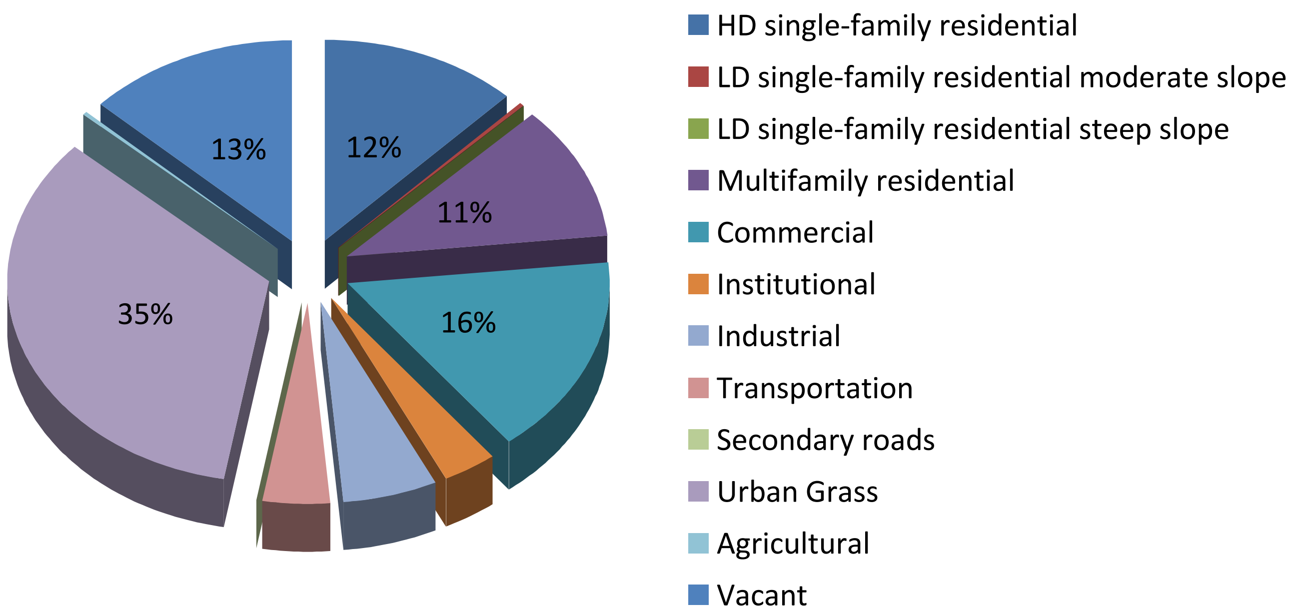


Figure 121. Land use distribution upstream of mass emission site SG02.

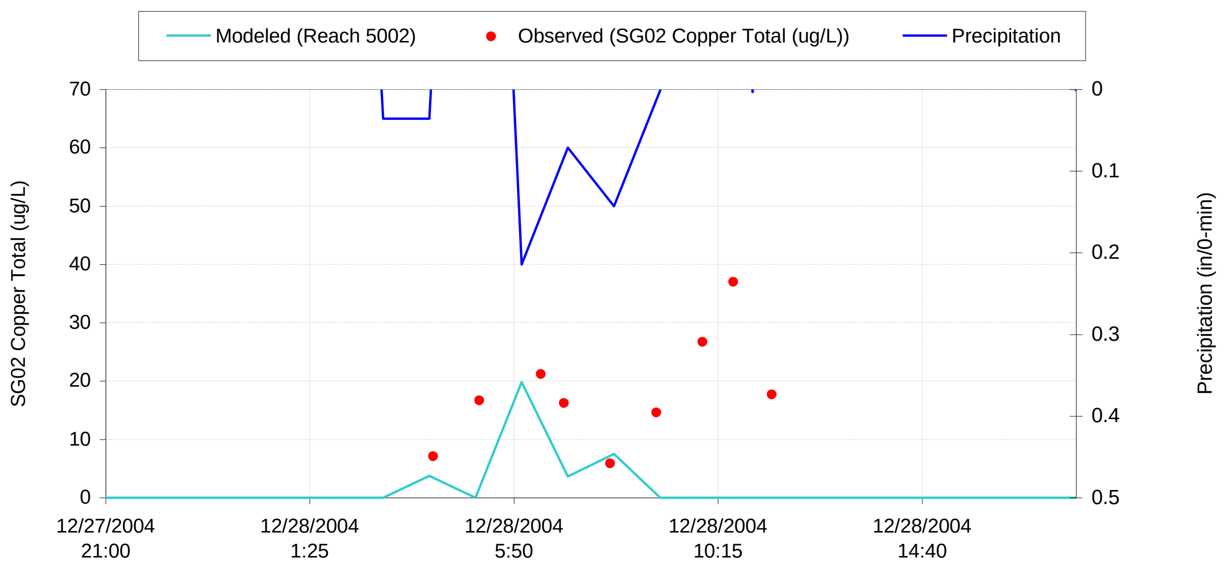


Figure 122. Modeled vs. observed SG02 Cu total (µg/L) at subbasin 5002.

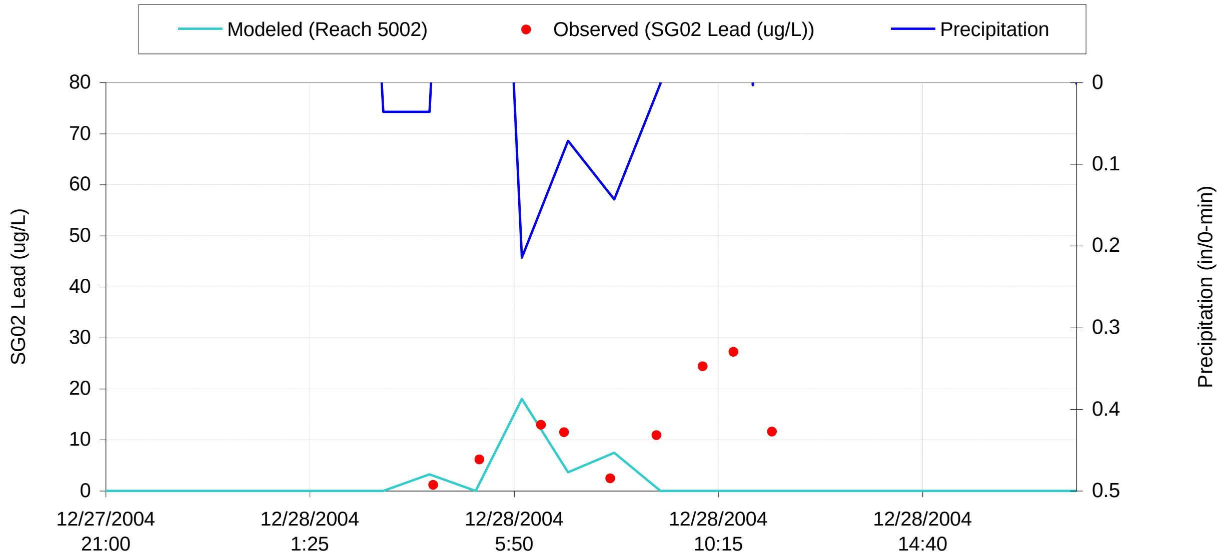


Figure 123. Modeled vs. observed SG02 Pb (µg/L) at subbasin 5002.

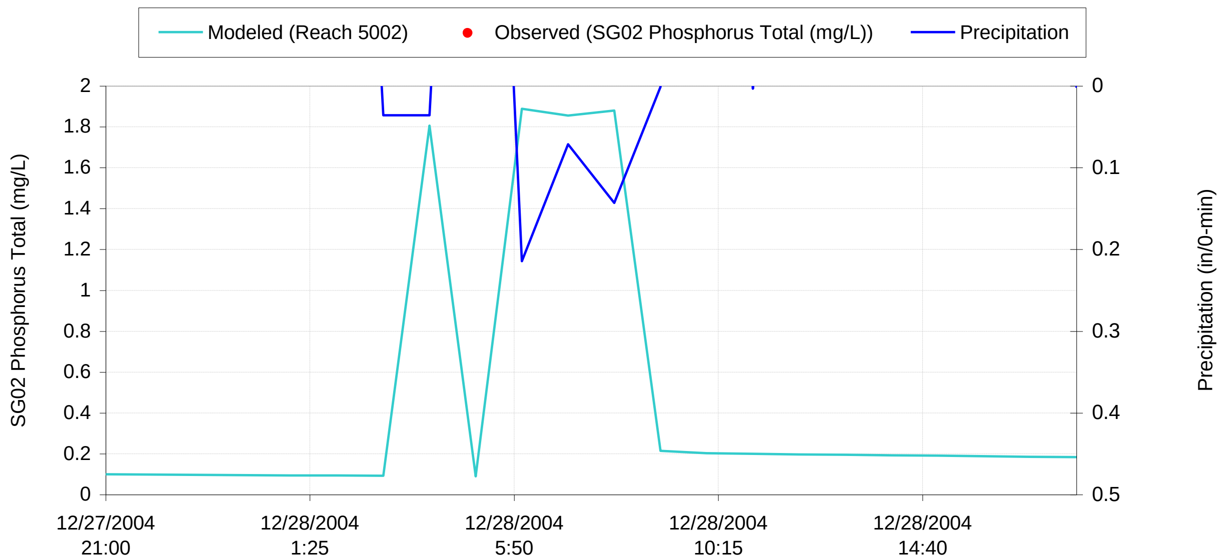


Figure 124. Modeled vs. observed SG02 phosphorus total (mg/L) at subbasin 5002.

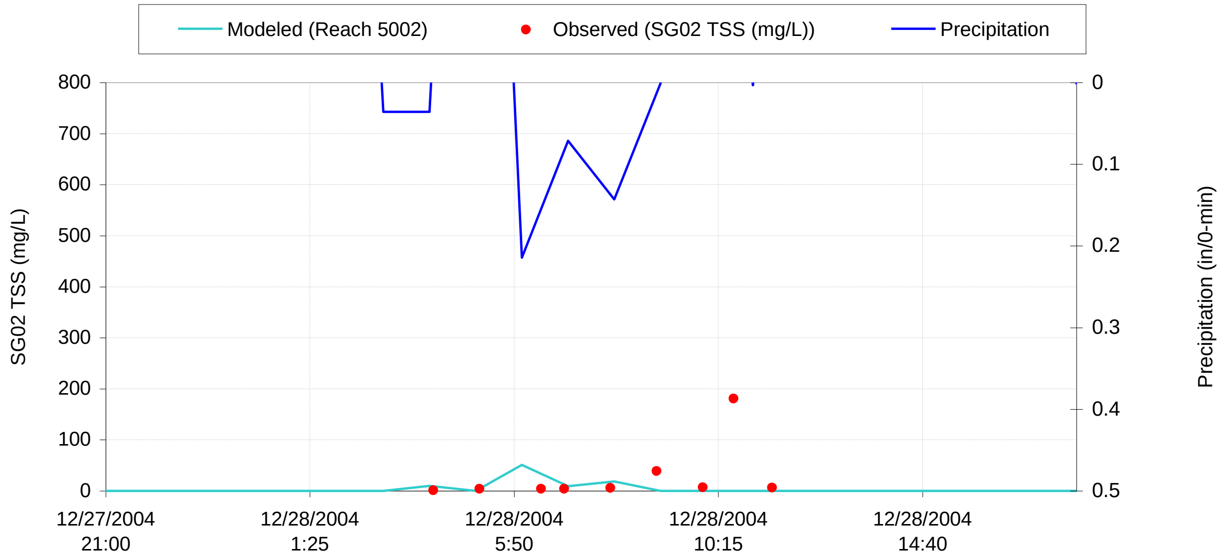


Figure 125. Modeled vs. observed SG02 TSS (mg/L) at subbasin 5002.

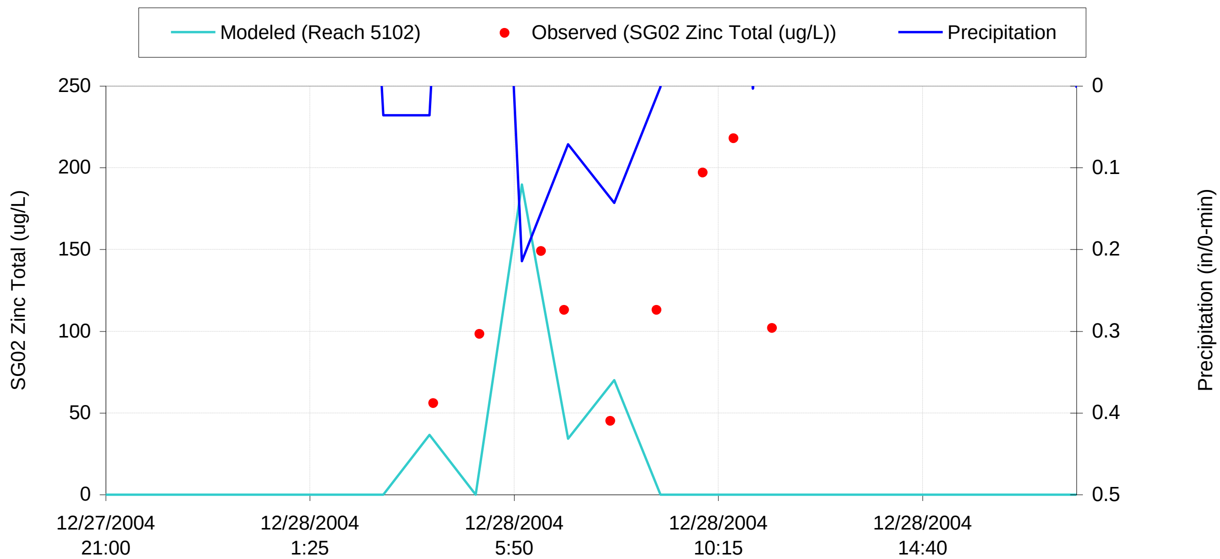


Figure 126. Modeled vs. observed SG02 Zn total (µg/L) at subbasin 5002.

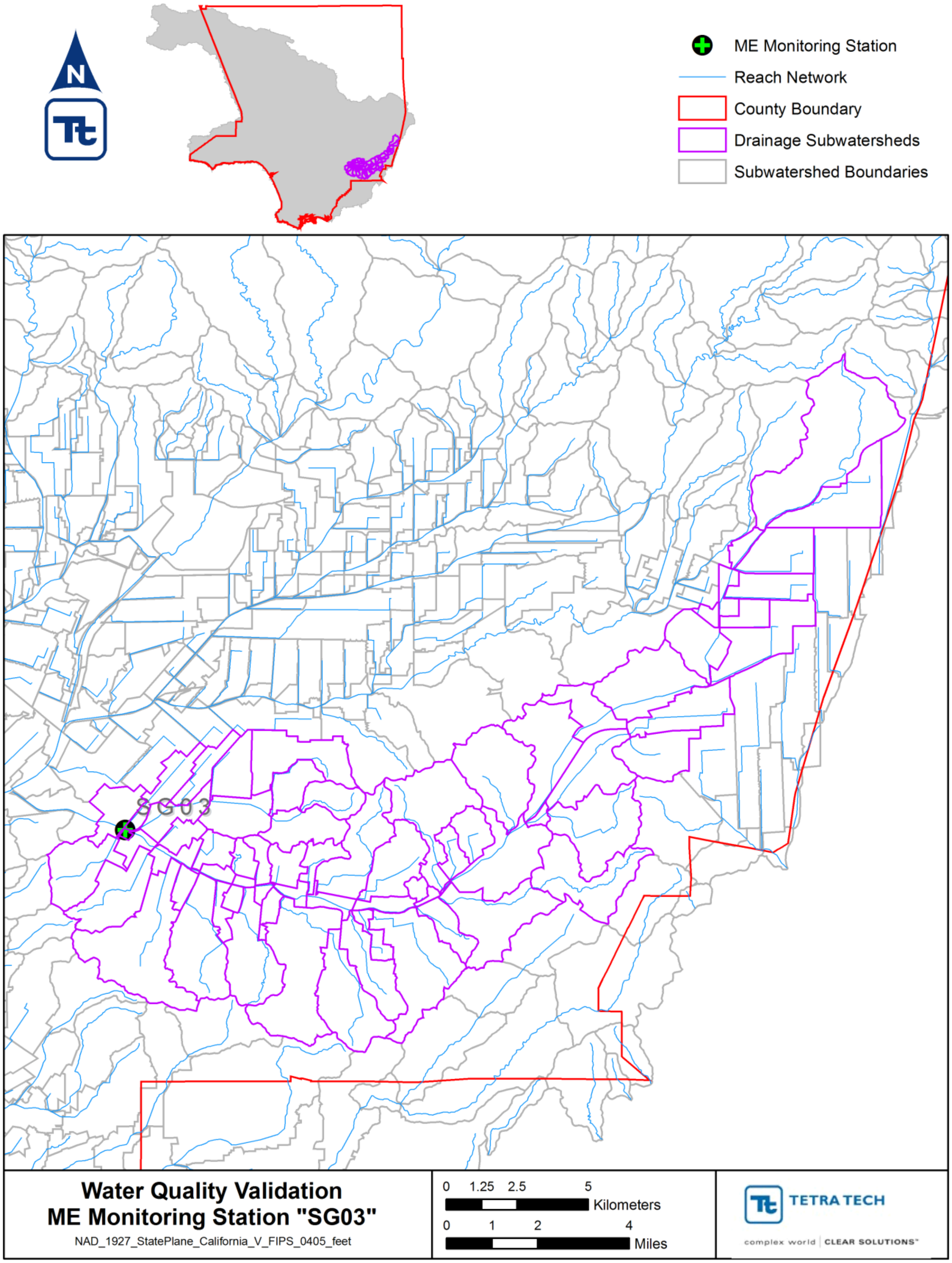


Figure 127. Location and drainage areas of mass emission site SG03.

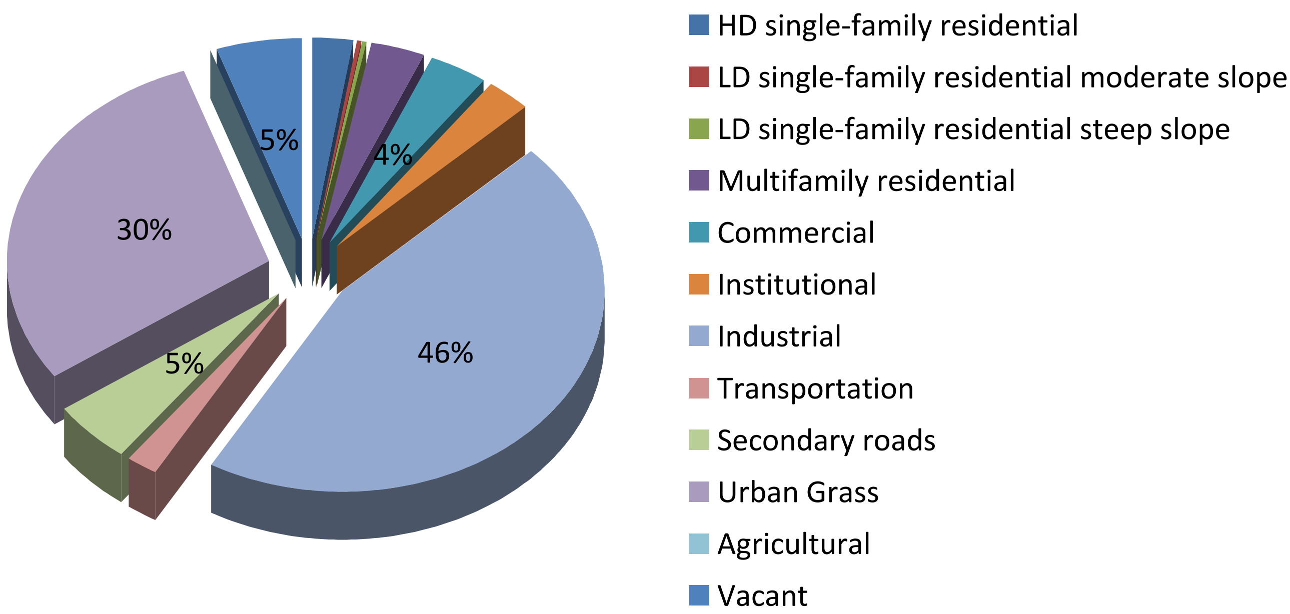


Figure 128. Land use distribution upstream of mass emission site SG03.

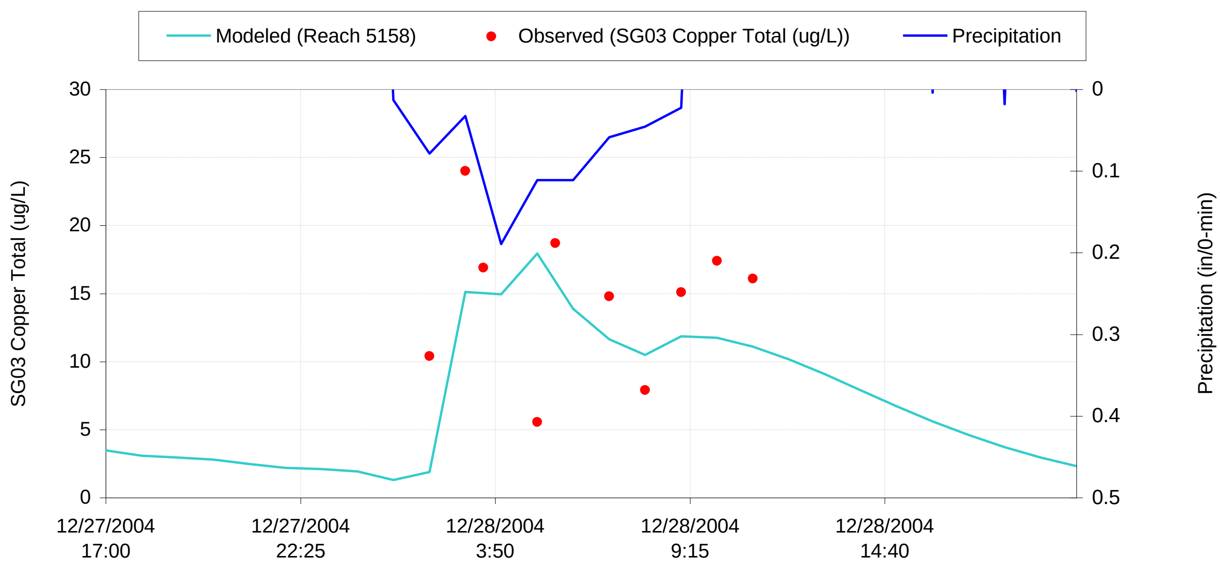


Figure 129. Modeled vs. observed SG03 Cu total (µg/L) at subbasin 5158.

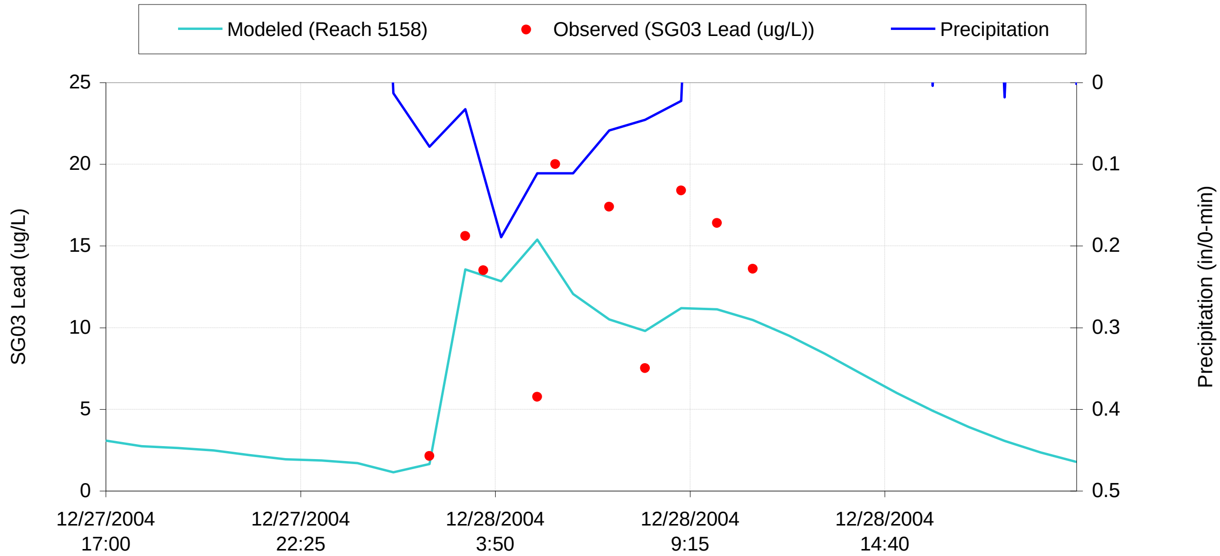


Figure 130. Modeled vs. observed SG03 Pb (µg/L) at subbasin 5158.

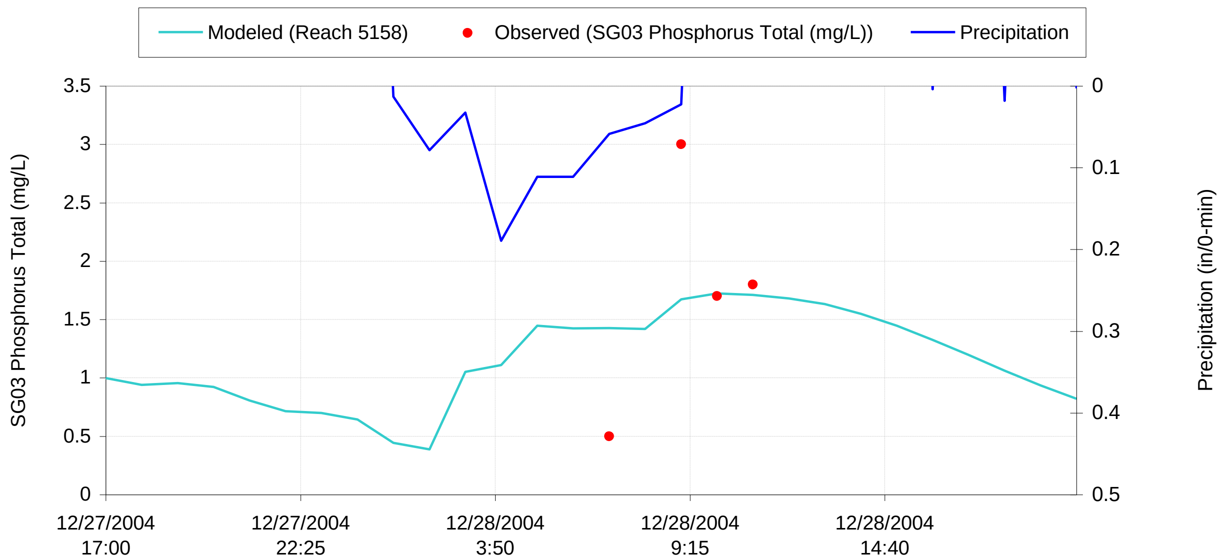


Figure 131. Modeled vs. observed SG03 phosphorus total (mg/L) at subbasin 5158.

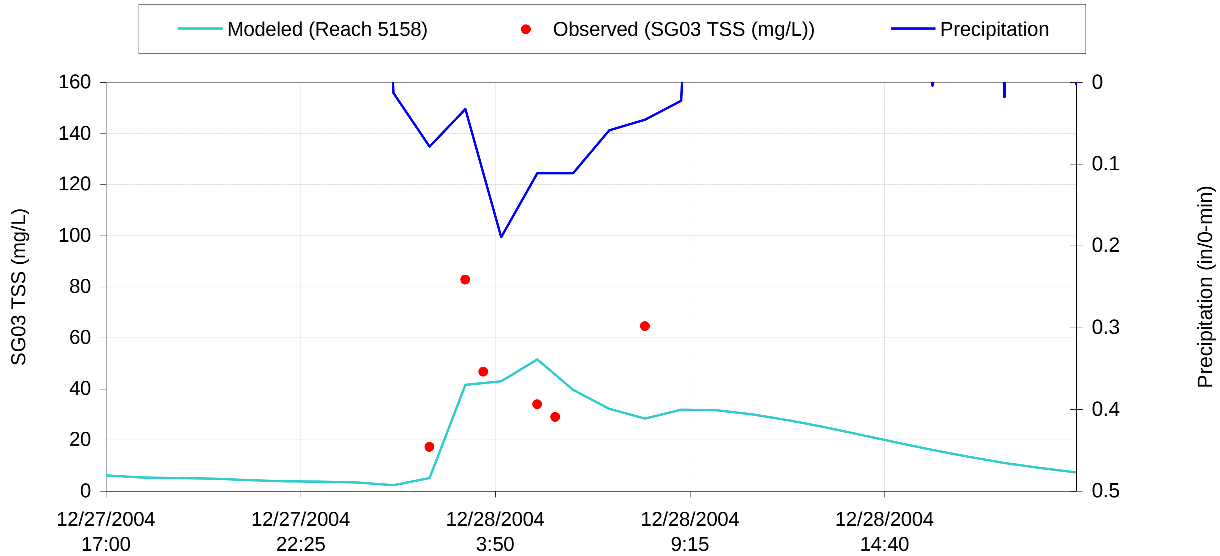


Figure 132. Modeled vs. observed SG03 TSS (mg/L) at subbasin 5158.

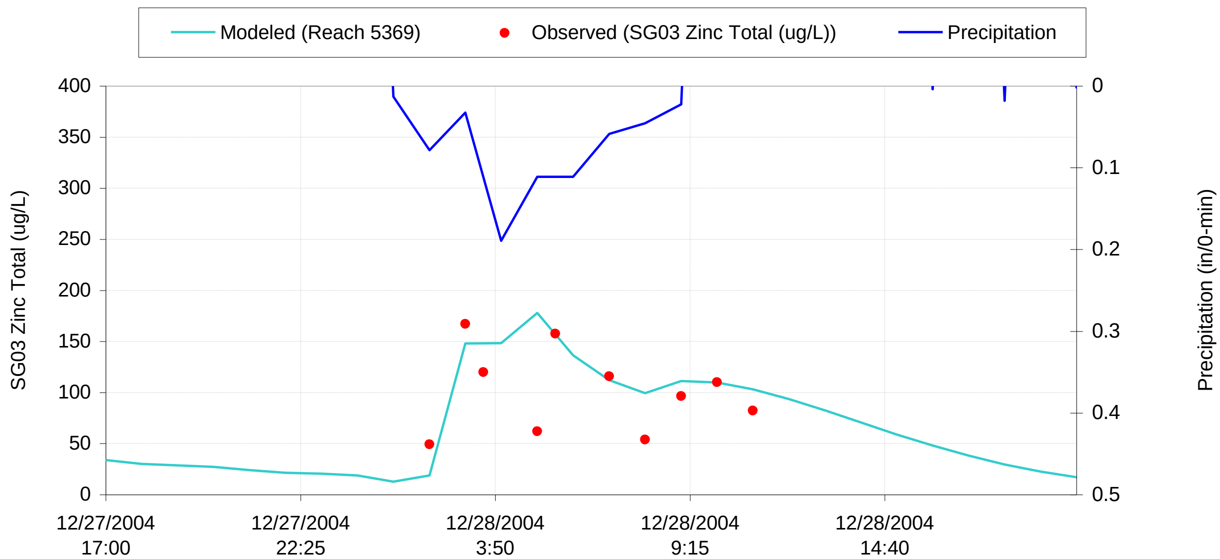


Figure 133. Modeled vs. observed SG03 Zn total (µg/L) at subbasin 5158.

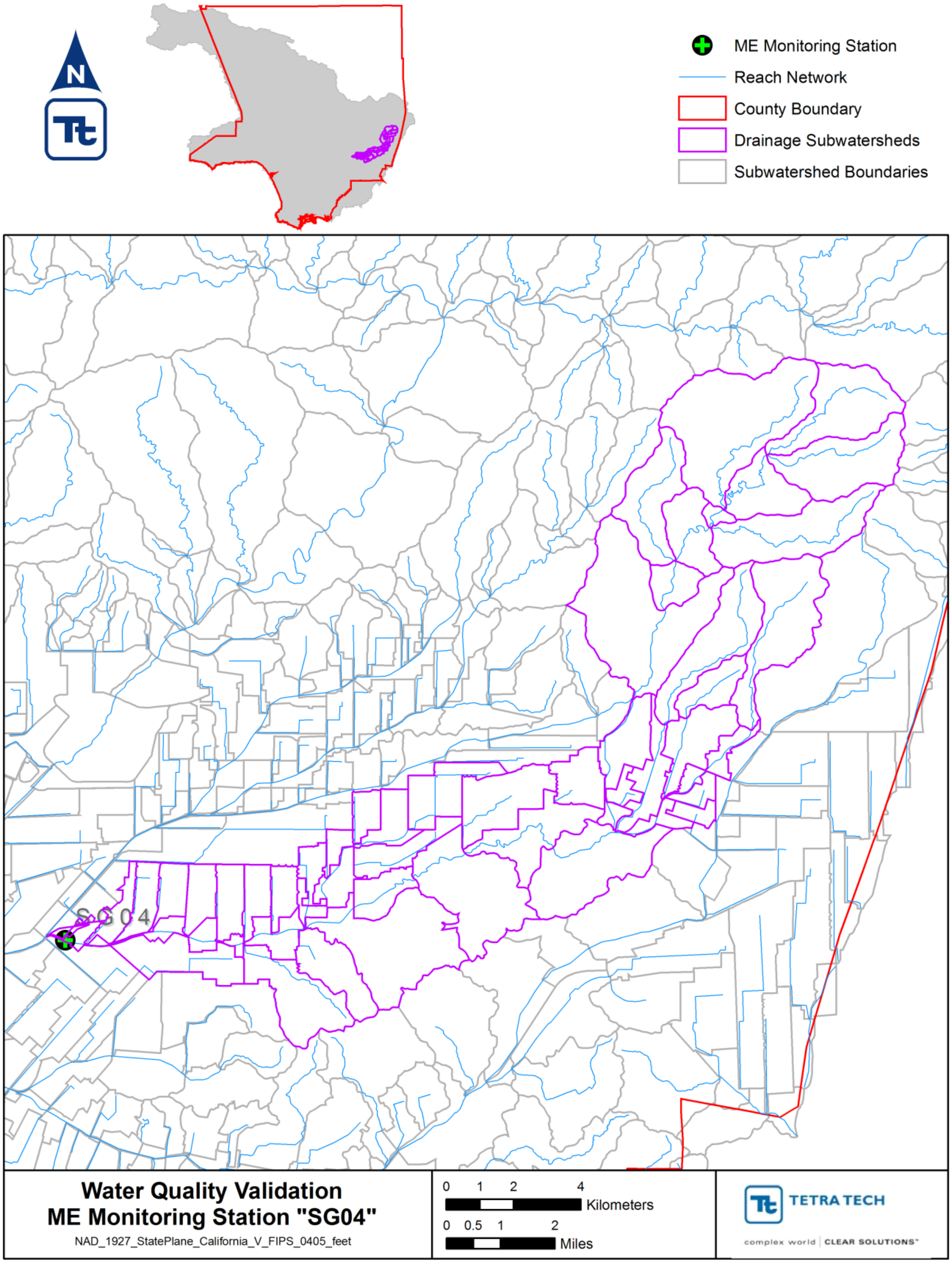


Figure 134. Location and drainage areas of mass emission site SG04.

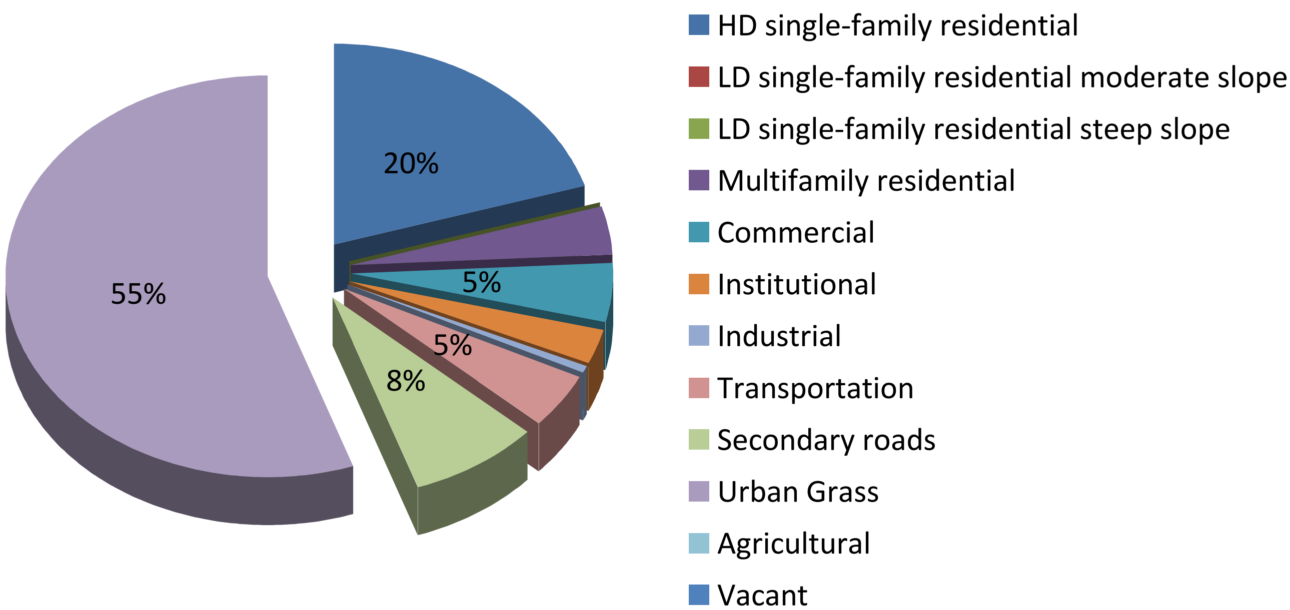


Figure 135. Land use distribution upstream of mass emission site SG04.

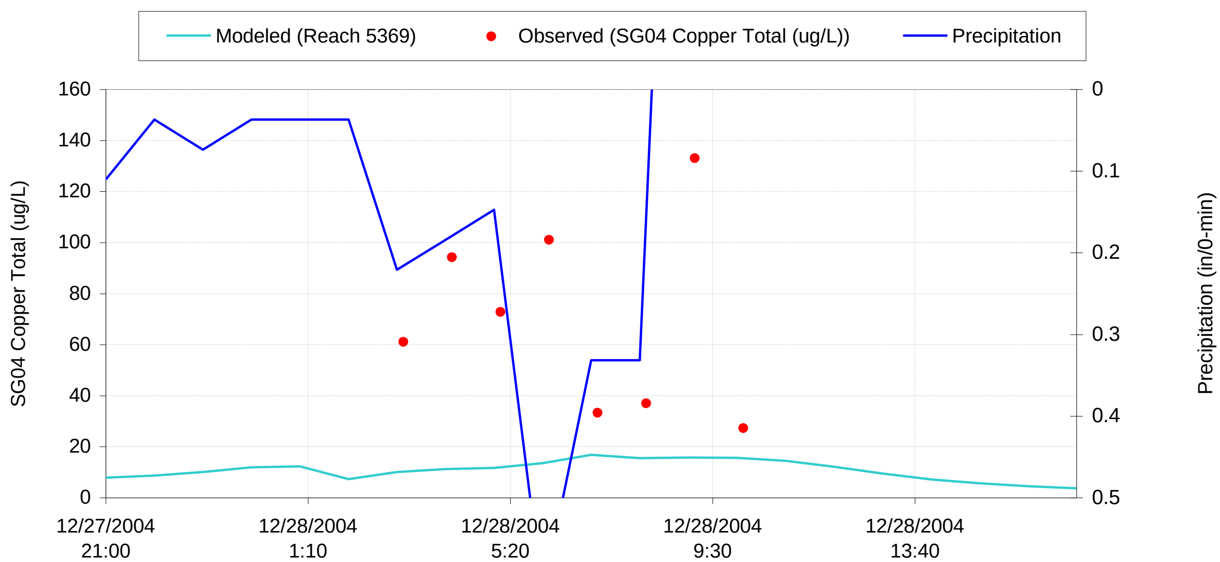


Figure 136. Modeled vs. observed SG04 Cu total (µg/L) at subbasin 5369.

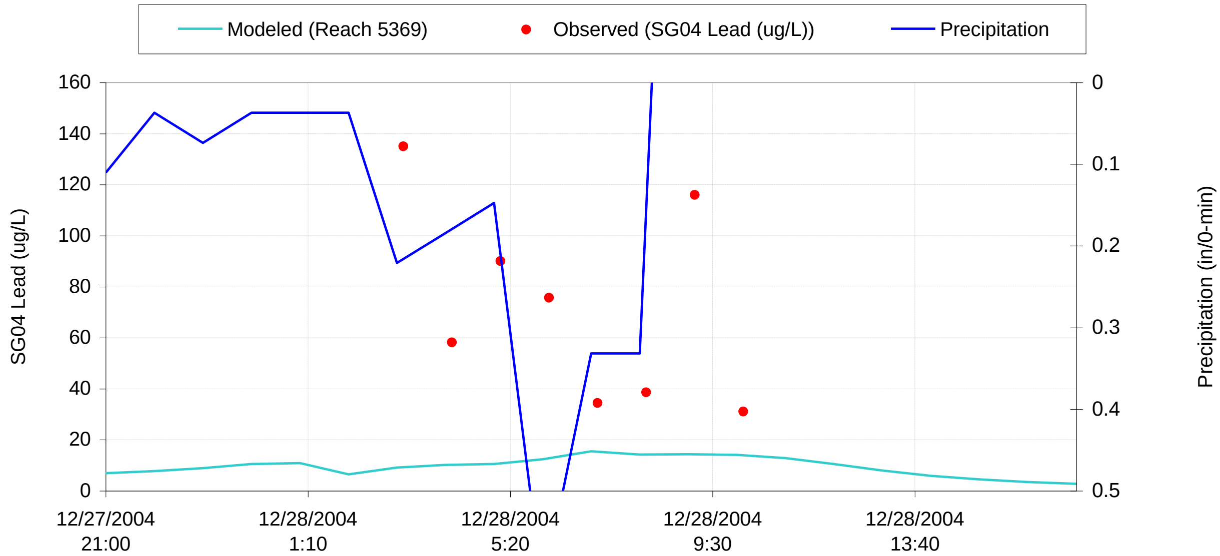


Figure 137. Modeled vs. observed SG04 Pb (µg/L) at subbasin 5369.

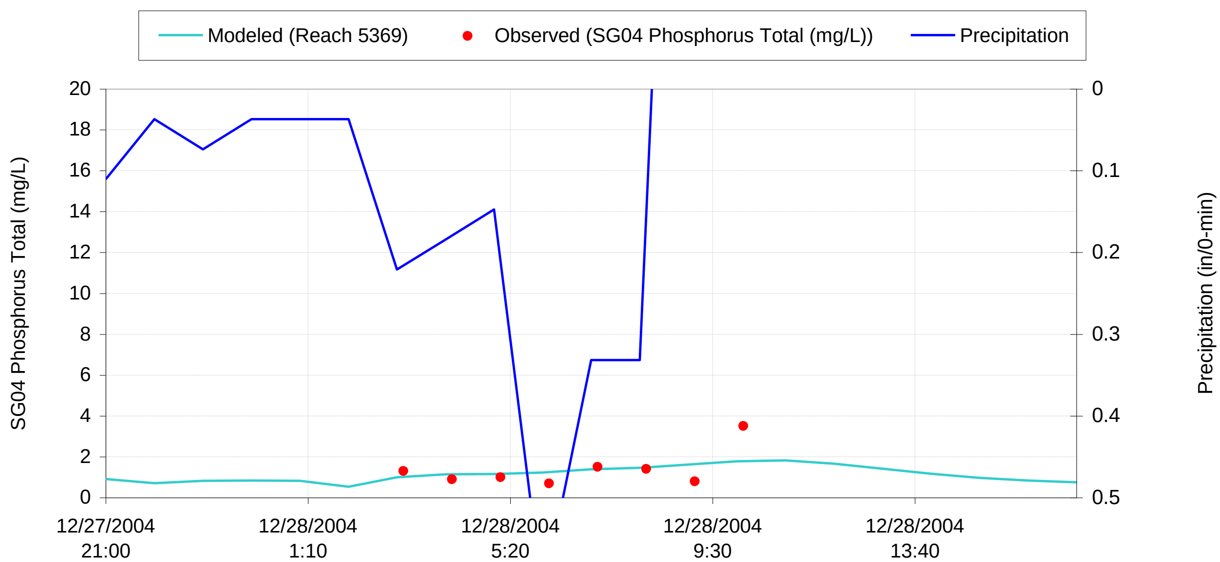


Figure 138. Modeled vs. observed SG04 phosphorus total (mg/L) at subbasin 5369.

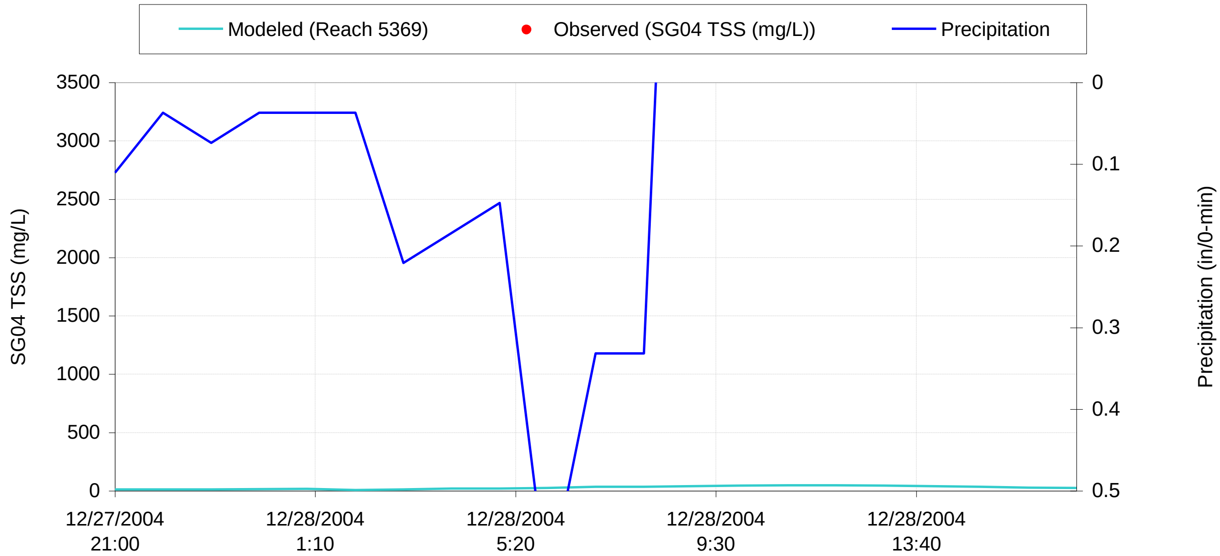


Figure 139. Modeled vs. observed SG04 TSS (mg/L) at subbasin 5369.

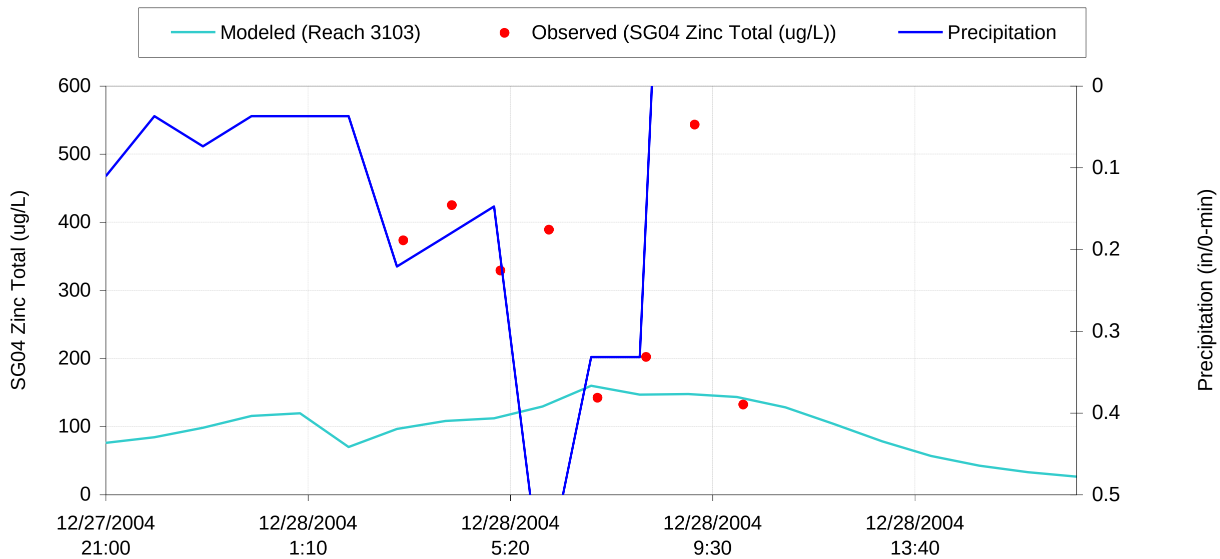


Figure 140. Modeled vs. observed SG04 Zn total (µg/L) at subbasin 5369.

Summary and Conclusions

In the Part I report, hydrology calibration benefited from the high-resolution spatial representation of meteorological patterns throughout the watershed, because comparisons were done using continuously observed flow data over longer periods. For water quality calibration (especially storm EMC calibration), the response is highly dependent on the fine-scale representation of the storm hyetograph. As seen in Appendix C, and in the validation time series graphs for the mass emission stations in the previous section, the successful representation of a runoff event was directly related to the representation of the specific rainfall hyetograph. Water quality data were collected for a series of short and flashy storm events at discrete intervals and small sites. For such short events, slight heterogeneity in precipitation will affect the precision of the hydrograph prediction and, therefore, the associated water quality behavior. Using the dense network of rain gauges available, the nearest 5-minute LADPW rainfall gage was selected for each land use location. When the data were either not available or representative of the actual storm, nearby daily gages were disaggregated to 5-minute intervals using nearby 5-minute stations. Although that provided a good estimation of the site rainfall, some hydrologic error is introduced into the individual calibration points. By using multiple storms and locations for calibration the water quality calibration was based on the dominant patterns.

The land uses used for simulation, although logically grouped into major categories, are not completely homogeneous in their composition and response to rainfall runoff events. For example, the Commercial general category had four land use site subcategories, as identified by SCCWRP, of (1) Road, (2) Mall, (3) No Homeless, and (4) Gas. Each of those sites exhibited a unique HRU surface type distribution as previously shown in Table 5. By modeling each site individually, the behavior of each site can be evaluated and the aggregate behavior of the general category estimated. The graphs provide a format to evaluate the range of responses with a general land use category. .

The model performance was limited in for selected land uses that were not broadly represented or sampled in the watershed. For example, horse farms were under predicted for fecal coliform for the selected site location. The calibration process avoided extreme adjustment of parameters for highly localized conditions that would adversely impact the broad scale use of the land use category.

The resulting calibration of the land use sites provides an excellent broad scale representation of the dominant land use categories represented in the basin. The calibration approach used a robust and systematic characterization of pollutant loading, adjustment of selected model parameters, and comparison to detailed water quality sampling data. The model predicts pollutant concentrations and loading consistent with the source assessment. The major behaviors are well represented including

- Relatively high concentrations of sediment from urban areas, especially road surfaces
- Relatively high concentrations of sediment-associated metals from urban areas
- High concentration of fecal coliform bacteria from agricultural and urban areas associated with pet waste
- Efficient mobilization and transport of sediment from impervious surfaces, especially roads

An interesting observation, one that could not be explicitly represented in the model but should be further investigated, was the pattern that the metals-to-sediment ratio exhibits during the course of a storm event. Figure 141 shows that the ratio tends to increase toward the *end* of the storm when the flow rate is subsiding (as opposed to the beginning first-flush). That is most likely associated with fine sediment particles that might not be as prevalent during the first flush of the storm but will tend to linger and transport with steady sheet flow associated with the end of a storm. That further suggests that the fine sediment seen toward the end of storms is most likely composed of dust from metals like Cu, which tend to accumulate on road surfaces from brake pads. The model uses a constant average potency factor to represent sediment-associated mass. This finding suggests that varying the ratio as a function of particle-size distribution in the future could help to better represent the actual physical behavior. That has potential implications on BMPs and modeling their associated effectiveness.

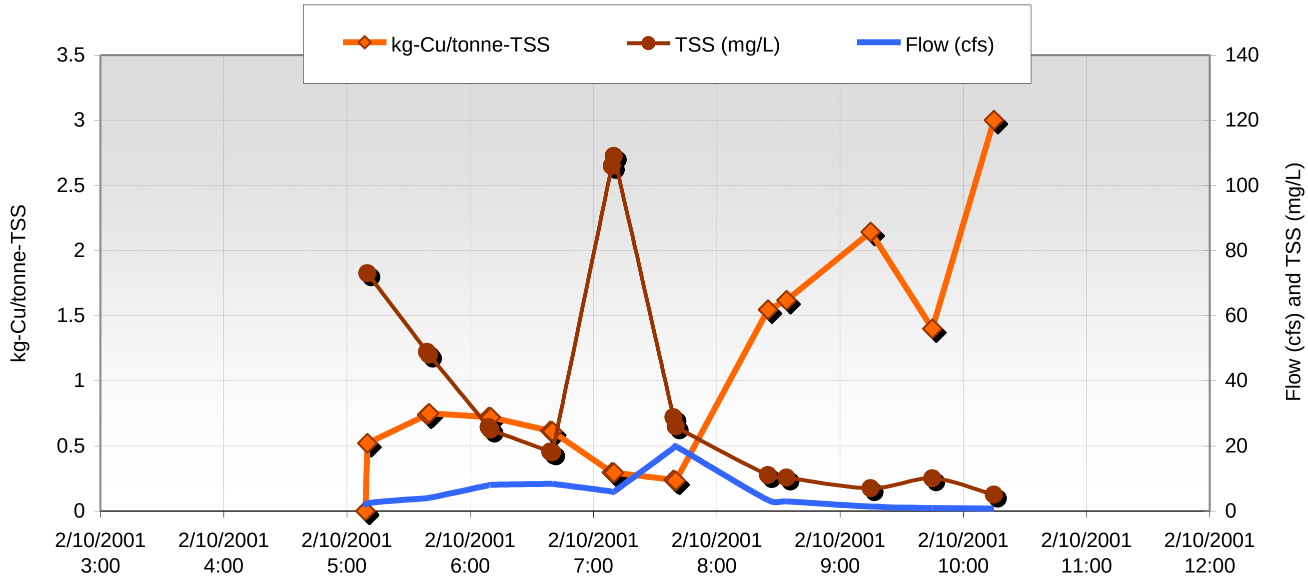


Figure 141. Observed Cu-to-TSS ratio variation during a selected storm event at LU01.

Finally, the validation compared the aggregate modeling predictions at downstream mass emissions stations, providing and excellent test of the ability of the model to reflect the response of the watershed to broad-scale land use management. The validation shows good response at most stations.

The use of physically based modeling incorporating the rainfall runoff behavior and land use site characteristics has resulted in a model that is designed to be sensitive to the local conditions and responsive to future changes in land management. By recognizing the impact of sediment detachment and washoff on water quality loading, the system is set up to simulate the benefits of management practices that protect land surfaces, reduce runoff, or trap sediment. The calibration and validation results demonstrate the ability of the model to represent the local conditions using available monitoring data and land use information.

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